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TECHNOLOGY SATELLITE DATA TO URBAN AND  
REGIONAL PLANNING: TEST SITE, COUNTY OF LOS  
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# APPLICATION OF EARTH RESOURCES TECHNOLOGY SATELLITE DATA TO URBAN DEVELOPMENT AND REGIONAL PLANNING

TEST SITE - COUNTY OF LOS ANGELES, SR-124  
FINAL REPORT

PRINCIPAL INVESTIGATOR: S. P. A. GENERAL ELECTRIC SPACE DIVISION

CO-INVESTIGATORS: J. M. KNIGHT, COUNTY OF LOS ANGELES

REGIONAL PLANNERS DEPARTMENT

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APPLICATION OF EARTH RESOURCES TECHNOLOGY  
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AND REGIONAL PLANNING  
TEST SITE - COUNTY OF LOS ANGELES. SR-124

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A project with a test site and users in Los Angeles, Calif., data funding and monitoring sources in Greenbelt, Maryland; program analysis and evaluation implementation in Valley Forge, Penna. and Los Angeles, Calif.; resources from Beltsville, Maryland and Daytona Beach, Florida; consulting support from Columbia, Maryland and Philadelphia and interested ERTS-watchers both across the U.S. and around the world necessarily involved personal and institutional interest and support of such a large magnitude that it would be literally difficult to acknowledge individually. Hence, this collective note of thanks to all those associated directly or indirectly with COLAGE.

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16. Abstract  <p>The Earth Resources Technology Satellite Data Use Experiment, for the Test Site SR-124, reported here had for its objectives: ERTS data validation, characteristics signatures generation via a multispectral information extraction system usage/evaluation and ERTS data utility assessment for urban and regional planning with methodologies development.</p> <p>The County of Los Angeles Regional Planning Department photointerpreted ERTS film products to define problems of interest to them as the primary user, coordinated ground truth over the complex test site including interfaces with secondary users as well as participated in on-line analyses of the GE multispectral information extraction systems, GEMS and IMAGE-100. The GE Space Division and OVAAC8 International Earth Observations Group co-investigators carried out the interactive machine analyses, developing techniques and procedures as well as evaluated the outputs, together with the County planners, for the immediate agency as well as the long-range community utility in urban and regional planning applications. Extensive aircraft underflight coverage was provided by NASA that was valuable both in inputs preparation and outputs evaluation of the machine-aided analyses.</p> <p>The standard film products from NASA were supplemented by non-standard products, principally from the GE Photoengineering Laboratory. One of the non-standard ERTS images led to the County Test Site Coordinator to discover a major new fault-lineament on the northern slope of the Santa Monica Mountains.</p> <p>Products from the GEMS/IMAGE-100 have been shown to have a variety of utility in urban and regional planning, especially in an environmental monitoring context.</p> <p>The synopticity, periodicity and multispectrality of ERTS data offer new opportunities to planners in information sources. NASA should involve the urban and regional planning community in a larger and more intimate fashion in earth observational programs.</p>		14. Sponsoring Agency Code	
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## PREFACE

This is the final report on an Earth Resources Technology Satellite Data Utilization Experiment, one of the three-hundred or so investigations selected by NASA for the Space Applications Program on ERTS-1. The project team members came from the General Electric Company Space Division, County of Los Angeles Regional Planning Commission and OVAA/C8 International Earth Observations Business Group. The test site, designated by NASA as SR-124, centered around the County of Los Angeles, and was named 'COLAGE', an acronym by which the project came to be known almost since its inception in July of 1972. The work reported here was carried out between July 1972 and June 1974.

The proposed objectives of the investigation were:

1. To validate ERTS imagery by correlation with the Los Angeles County ground truth
2. To generate characteristic multi-field signatures for the ERTS sensors
3. To ascertain the utility of a multi-spectral analyzer under development through its use by representative multi-resource users
4. To evaluate the utility of ERTS imagery for developing planning and environmental data bases and information systems
5. To investigate the feasibility of using ERTS output for research in urban and regional planning methodologies.

The scope of the work carried out under this project was determined by these objectives, the availability and the content of source and reference data, the tools for analysis, interaction amongst the team members as well as with other investigators and the resources available for the investigation.

The research and development nature of the Earth Resources Technology Satellite Mission of NASA itself reflected in the orientation for this experiment. Thus, in view of the novelty of the ERTS-1 data as well as the developmental character of the multispectral information extraction systems GEMS and IMAGE 100 available to the investigators, an intensive effort was made to ascertain the data content (the first objective 2) above in formulating the subsequent experiments rather than set the latter a priority. This consideration was reflected in the Data Analysis Plan formulation (outlined in Section 2), with the actual plan implementation proceeding in scope beyond the earlier expectations.

Both manual photointerpretation of the film products as well as machine analysis of transparencies and tapes were carried out in parallel, often iteratively. Again for the photointerpretive effort, more non-standard products - scale-wise and band-filter - wise - became available than had been anticipated. One finding from a non-standard product was the discovery of a new geological fault-lineament or the northern slopes of the Santa Monica Mountains from the December 14, 1972 imagery, (described in Section 3).

The interactive machine analyses, both by analysts as well as the users on the team, were a major segment of this investigation, as the second and the third objectives above indicate. The focus in these analyses (discussed in Section 4), was on obtaining results of interest in urban and regional planning applications while concurrently developing insights into techniques development.

The evaluation of these results required not only ground truth that was already on hand at the County, that which could be recalled mentally by the planners while interacting on-line with the machines, the timely data supplied by secondary users within the test site (all as described in Section 6), but also the invaluable aircraft under flights data (summarized in Section 5). The quality, coverage, schedule and variety of underflight data again were better than had been expected while proposing: some of the sensor configurations having been flown operationally for the first time while underflying for this investigation. The comprehensive and seasonal aircraft data has been and will continue to be used intensively operationally by the Regional Planning Commission.

A primary conclusion from this investigation is that ERTS data, with its synopticity, periodicity and multispectrality, has significant utility in urban and regional planning for agencies whose jurisdiction extends over a major portion of or covers multiples of an ERTS frame. While photointerpretation of ERTS imagery yields much valuable information, machine analysis of ERTS data offers results and output formats that have potential for more novel application to problems in urban and regional planning..

Amongst the recommendations from this study, principally addressed to NASA and the remote sensing community, is the need to involve urban and regional planners (e.g., on panels at symposia, seminars, etc.) so that their requirements can be presented to put this discipline/application in a more realistic and operational perspective. Minimally, it should be realized that urban and regional planning is a much broader activity than land use planning which itself involves much more than gathering current land use.

This report is addressed both to the remote sensing community, who has been partially reached by previous reports on the earlier phases of this investigation, as well as to the urban and regional planning community who need to be reached more for a fuller realization of the potential of ERTS data utilization.

Questions or comments by readers can be addressed to any of the investigators as convenient.

SECTION 1

INTRODUCTION  
AND  
OVERVIEW

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## SECTION 1

### INTRODUCTION AND OVERVIEW

#### 1.1 INVESTIGATION OBJECTIVES AND SCOPE

As originally stated in the proposal for the ERTS A Data Use Experiment, the objectives of this investigation were:

1. To validate the ERTS A imagery by correlation with the Los Angeles County ground truth
2. To generate characteristic multi-field signatures for the ERTS sensors
3. To ascertain the utility of a multispectral analyzer under development through its use by representative multi-resources users
4. To evaluate utility of ERTS imagery for developing planning and environmental data base and information systems
5. To investigate the feasibility of using ERTS output for research in urban and regional planning methodology

While proposing, these objectives were characterized as NASA-goals-oriented-primarily (1) and (4), secondarily (2) and (3) -; scientific and technical community-oriented-primarily (2) and (3), secondarily (1) and (4) -; and finally user-community-oriented - (1), (4) and (5). Certain of the objectives were also then recognized as short-term, the accomplishment of which could be demonstrated at the conclusion of the study by the team members and therefore evaluable by NASA, the sponsor of this research project. The first three objectives fell in this group. A somewhat longer term was the fourth objective, which was rather dependent on the state of the data base and information system extant for such an evaluation of the ERTS imagery. A much longer term objective was the fifth objective, evaluation of whose achievement is expected to be done partly by the planning community at large.

The approach that had been proposed for the investigation to achieve these objectives, determined the scope of the study. The approach could be characterized as interactive in a multiple sense: in the technical exchange between the multidisciplinary team members; in the user involvement through every phase of the effort, from data request during the proposal and the investigation, in the data analysis, results evaluation and communication; in the system or facility for machine analysis of the data and finally in the team's relatedness to the ERTS community at large.

The scope of the study was to focus primarily on ERTS data analysis, use and evaluation for urban and regional planning application. Acquisition and scrutiny of correlative data, namely the ground truth and aircraft under-flight products, were determined by their relevance to ERTS data analysis. While working with an operational user, the nature of the investigation was essentially a research and development effort fully consistent with the nature and goals of the NASA-ERTS system and mission. The nature of the data analysis aided by machines was also research and development oriented. If the analysis results were of an operational nature, as they often appeared to be, this was an asset.

It would be instructive to review in retrospect what the investigation team's assessment is of achieving the proposed objectives. This is best deferred to the last section of the report, by which time the reader would be in a better position to evaluate the team's assessment against the reported results. See Section 8.

#### 1.2 INVESTIGATION ELEMENTS AND REPORT SYNOPSIS

A brief review of the background of the investigation vis-a-vis, the investigators' orientation, the team composition and program plan would give the reader a project overview. This is presented in the remaining paragraphs of this section.

One of the early contractual requirements by NASA was a Data Analysis Plan formulation, review and approval before the effort could proceed. An outline of the plan is presented in Section 2. It is briefer than the originally submitted Data Analysis Plan since much of the detailed discussion is taken up elsewhere in this report.

The original intent of the investigators was to analyse, use and evaluate every kind of ERTS-data product applying both the classical photointerpretation procedures as well as machine-aided methods. Highlights of the photointerpretation studies are presented in Section 3. After briefly describing the features of electronic data analysis generally and of the multispectral information extraction systems used in this investigation specifically, the illustrative case studies using these facilities with ERTS data, both in transparencies and on tapes, are discussed in Section 4.

The studies described in Sections 3 and 4 were conducted in parallel or simultaneously. Corroboration of the manual and machine analyses had been anticipated to require underflight reference data. Such underflights were scheduled and flown by NASA under its Earth Resources Aircraft Program in support of most ERTS investigations. Those carried out over Test Site SR 124 are summarized in Section 5.

The major function of acquiring the necessary ground truth for ERTS data analysis corroboration and of evaluating and applying the results fell on the primary user, the County of Los Angeles Regional Planning Commission. This activity, plays that of interfacing with secondary users again to acquire additional ground truth and further corroborate and communicate the results, was developed in the investigation as that of test site coordination. It is described in Section 6.

The review of analysis results from Sections 3 and 4 and of reference data from Sections 5 and 6 sets the stage for an evaluation of the utility of the data. This utility for urban and regional planning applications is summarized in Section 7. Factors bearing on the utility evaluation are discussed earlier in that section against which the later utility discussion is to be reviewed. It might be mentioned here that the discussion in Section 7 evolved over a good deal of the latter days of the investigation. It would be tempting to present the considerations bearing on the utility of ERTS data earlier in the report to set the stage, so to say, for the discussion of the investigation studies themselves. However, that would mislead the reader in giving an after-the-fact impression of how the investigation could have been logically structured, etc. To the extent that the Final Report of any project is to reflect both the history and the practicality of the as-it-happened situation, the reporting sequence here follows historic chronology.

The retrospective review of the investigation objectives, conclusions, recommendations and suggestions for further investigations are presented in Section 8.

Certain background and supplemental materials on ERTS system and mission, GE multispectral information extraction systems, aircraft underflights summaries, etc., that would increase an appreciation by the user of the main text of the report is included as appendices.

In certain sections where the investigation results/summaries are on 35 mm slides, it was best suitable to group the illustrations in one place.

### 1.3 PROPOSAL CONSIDERATIONS

Even before the unmanned checkout phase of the Apollo Program to land men on the moon, efforts were undertaken to focus attention of the U.S. aerospace community on the problems of the human environment. Intensive discussions were held in the 1960's among aerospace technologists, scientists and users that pointed up the benefits to be derived through development of the earth-observing satellite to aid in solving some of the problems.

As part of the ERTS program NASA designated over 300 experiments from around the world, from the academic community, industry and government agencies as user, investigators, all of whom have well-defined projects aimed at the solution to an earth resources problem. NASA supplies the users with ERTS

products to aid in their investigation, monitors their efforts, and disseminates findings to other users with similar interests.

ERTS\* had not yet been launched when GE established a study team of technologists from its Urban Systems Organization who responded to an RFP on Data Use to NASA to investigate the utility of ERTS data for planning applications for a large city. The study team proposed to interest a planning commission of a large urban area in analyses of imagery from ERTS-1 and high altitude aircraft. The team visited planners in several large cities including Toronto, Seattle, San Francisco and Los Angeles. The County of Los Angeles Regional Planning Commission expressed interest in the study and together the Commission and GE prepared a proposal of their intentions that was submitted to NASA late in 1971.

Traditionally, planners have relied on manual techniques to analyze photographic data returned from aircraft. This method is not only tedious, but inadequate compared with analysis with the use of electronic machines. About six years ago, General Electric began the development of a system for analyzing multispectral imagery electronically. The first working system was designated GEMS for General Electric Multispectral System. It was available in the early part of the COLAGE investigation. A more diversified IMAGE 100 was available toward the end of the Los Angeles study.

The site chosen for the study had to be sufficiently complex and varied in terrain to permit investigation of different aspects of an urban area. Los Angeles offered that complexity to a far greater degree than any of the other municipalities considered.

The user was required to become involved in the day-to-day study effort. To this end, members of the staff of the Los Angeles County Regional Planning Commission exhibited a pioneering spirit and added their specialized knowledge in the pursuit of new tools for use in urban planning.

Both the program and the team were multidisciplinary. It was the intention to investigate regional aspects of planning rather than isolated land use activities. The members of the team came from varied backgrounds that ranged from regional planning to aerospace engineering.

Interactive analysis was defined as man working with the results provided on-line by the machine. Because of their specialized knowledge of the Los Angeles area and their familiarity with the techniques of photointerpretation, the LA County Regional Planners derived a wealth of information from the ERTS and aircraft imagery.

#### 1.4 PARTNERSHIP FUNCTIONS

The relationship of the participants in the COLAGE Project are shown in Figure 1-1. They include NASA/Goddard Space Flight Center, the General Electric Company Space Division, the Regional Planning Commission (RPC) of the County of Los Angeles, and OVAAC8 International. NASA supplied the data used in the project. This data not only included processed ERTS imagery, but also imagery derived from aircraft underflights. In addition, NASA provided scientific and technical monitoring of the project as well as offered a forum for the exchange of information. A number of panels reviewed the project findings under NASA's auspices.

Both aircraft and ERTS data was considered source information. The ERTS data was supplied in 70 mm format, 9-1/2 inch transparencies in both color and black and white, false color composite prints, and computer compatibility tapes. These products are described in detail in Section 2 under Data Analysis Plan Elements.

General Electric was the prime contractor and principal investigator. GE supplied technical direction and a thrust to the investigation. Electronic analysis of the data was performed by General Electric chiefly through GEMS and the IMAGE 100 equipment.

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\* ERTS-1 was launched on July 23, 1972. See Appendix A.

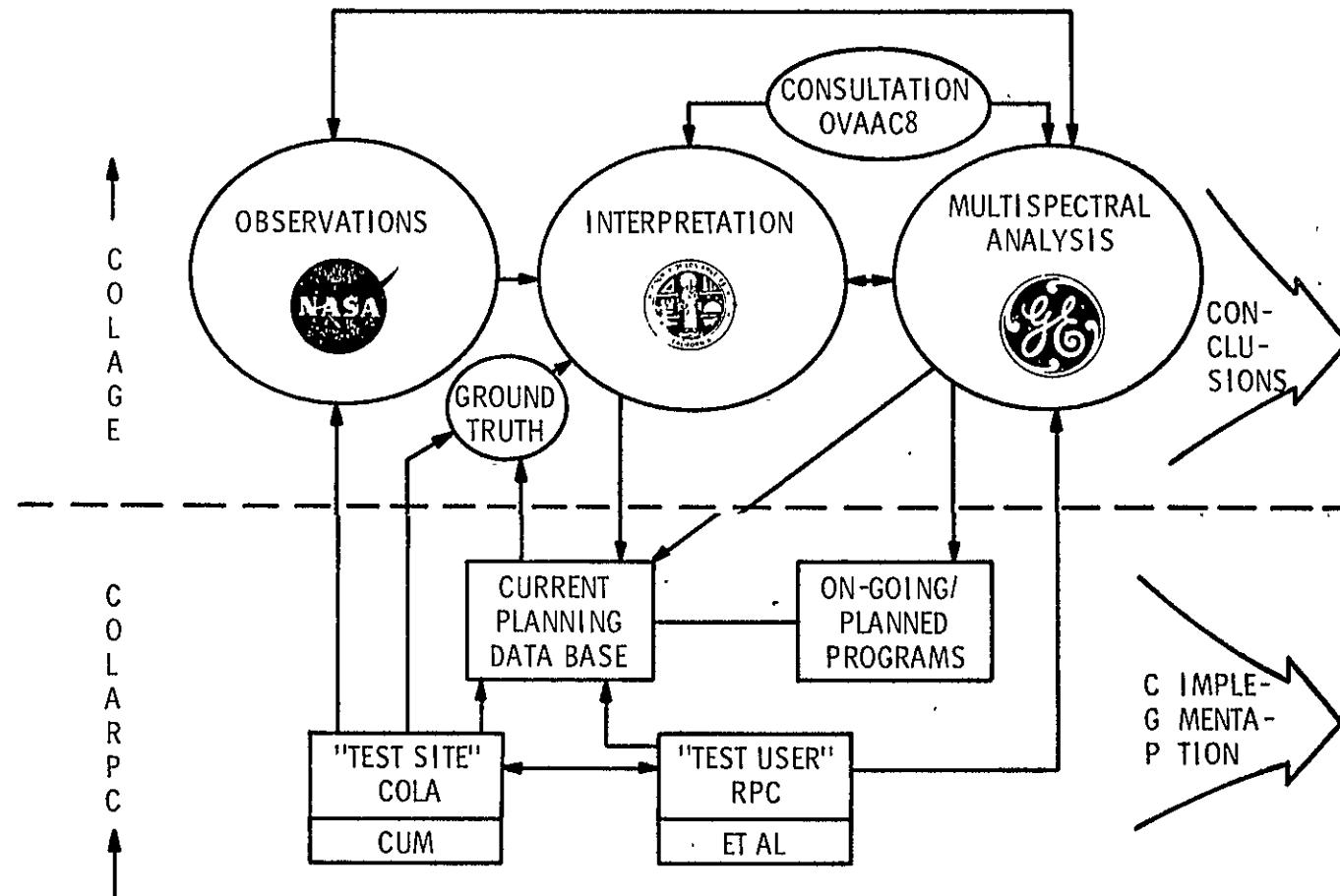


Figure 1-1. COLAGE Project Relationship

The investigation was developed around the needs of the County of Los Angeles. Because of their specialized knowledge of the County and its requirements, the Los Angeles County Regional Planning Commission provided the user inputs, ground truth of the test site, and photointerpretation of the data. The Los Angeles RPC also analyzed the extracted information suited to its overall objectives. Members of the Commission Staff participated with GE in much of the electronic data analyses. On several occasions during the investigation, members of the Los Angeles RPC Staff joined members of the GE team at Valley Forge, Penna., (where the GEMS was available) and at Daytona Beach, Florida (where the IMAGE 100 equipment was installed). Electronic analysis of this type relies on the interaction with the user who has particular knowledge of the ground truth of the area under study. The Los Angeles RPC determined the utility of the information produced by the GEMS/IMAGE 100 analysis.

The final major participant in the investigation was the Earth Observations Business Group of OVAAC8 International. They contributed to the design of data use experiment, urban and regional planning, and multispectral information extraction systems expertise. Their services were obtained by GE with NASA's concurrence as an overall interface among the participants. OVAAC8 took a broader view of the findings and represented the requirements of the general planning community as well as provided basic insight into ERTS data characteristics vis-a-vis multispectral systems analysis.

#### 1.5 PROGRAM PROGRESSION, PROJECT MILESTONES

The COLAGE Program proceeded according to the events listed in Table 1-1. From the beginning of the project there was an acceleration both in the type of data that was made available and in the capability for the analysis. The first data of the Los Angeles test site was a standard ERTS image at a scale of 1:1,000,000. Even though later data was of more value in the total analysis, the first ERTS scene made in August 1972 was an "eye opener" both to GE and the members of the LA County Regional Planning Commission in terms of the extent of coverage, and the potential it offered as a new tool for urban planning.

At the "kickoff" meeting in August of 1972, certain items emerged as of primary interest to the County. Emphasis was focused on the County alone and then the region around the County emerged as a result of this first meeting.

By December 1972, imagery from aircraft was made available. These scenes were taken with an RC-10 camera on board a U2 aircraft. The imagery was at a scale of 1:127,000, approximately the scale of the maps used by the County for policy planning.

Just as there was an improvement in data as the project progressed, so too there was a progressive improvement in the quality of the analysis. For almost a year, the project was restricted to the use of color composite images as inputs to the GEMS equipment, but in the Fall of 1973, the IMAGE 100 equipment became operational, and computer compatible tapes received earlier could be used as inputs. There was an improvement of several orders of magnitude in the results of the analyses with these tapes as inputs because an interactive analysis with the human investigator was possible with this equipment at ERTS data threshold. Appendix B gives a summary of the system operation and machine analysis techniques used in this investigation.

Initially, the machine analysis followed the conventional training and testing method, for substudies described in more detail in Section 4. But late in 1972, the investigators focused attention on the slicing and clustering approach. Since then, the method has been an iteration of both training and slicing.

Prior to the Mid-Project Conference organized under COLAGE auspices, "Southern California Views of ERTS," in May 1973, the investigators had analyzed standard ERTS images at 1:250,000 scale in color composite form from GE's Photolab in Beltsville. Also, at this time, the Hughes Aircraft Company (designers of the ERTS Multispectral Scanner) made a black and white image available for study at a scale of 1:80,000.

A mosaic of the entire State of California was made from ERTS images by the GE Photo Laboratory and used for analysis in December 1973. This data included an enlargement of the test site itself.

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Table 1-1. COLAGE Project Milestones

Data				Analysis			
Date/Month	Vehicle	Scale	Sensor/ Format	Photo Interpretation	System for Machine Analysis	Machine Technique	Application
June 30, 1972	Simulated Data						Program Initiation
July 23, 1972							ERTS-1 launch
August 10, 1972	ERTS	1:1,000,000	MSS Film	Standard	GEMS	Training/Testing, Photomodes	Water, Agriculture, Urban Areas
August 30, 1972							Kick-off meeting at LA
September 22, 1972							1st Symposium at GSFC
October 21, 1972	ERTS		MSS Film	Non-Standard Composite		Slicing/Clustering	Urban Core
December 14, 1972	Aircraft: U2	1:128,000	RC10			Slicing/Clustering	First Underflight Aircraft Imagery for COLAGE
March 14, 1973	Aircraft: U2	1:32,000	A3			Hybrid	Spring Scene of LA
March 1973							2nd Symposium at Goddard
May 7, 1973	Aircraft: Cessna					Hybrid	ERTS View of S. Calif. Mid-Project Meeting at LA, COLAGE-flown Light Aircraft Underflight
June, 1973	ERTS	1:250,000 1:80,000		Oblique Coverage			Residential Areas, Few Pixel Studies
July 2, 1973	Aircraft: U2						Aircraft Data Machine Analysis
October, 1973			MSS CCT		IMAGE 100	Transforms Training-Class- ification	Housing Analysis, Few Pixel Re- analysis
November 2, 1973	Aircraft: C130	1:24,000	CCT Hasselblad RC8 MSS IR	Multisensor		Slicing/Clustering	ERTS-Aircraft Registration
November 1973							NASA Interview With Team Members
December 1973							3rd ERTS Symposium in Washington
June 1974							Study Concluded
December 1974							Final Report Draft, Review

Finally, multi-sensor data of the test site covered by a C-130 aircraft was made available for evaluation in early 1974. Of special interest to the GE-OVAAC8 co-investigators was the Multispectral Scanner on-board the C-130 flights with 24 channels of data as compared to only 4 channels in the ERTS MSS. This aircraft scanner data was initially converted to "pseudo-ERTS" format so it could be input for machine analysis (selecting 4 bands per run) on the IMAGE 100 during September, 1974. Subsequently, capability to read the aircraft scanner data directly up to 16 channels simultaneously has been developed by GE at Daytona Beach. Analyses of the full complement of that data will be carried out post-project fashion, as so many of the items initiated during this investigation will no doubt be continued efforts by the County of Los Angeles, General Electric, and OVAAC8 International.

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SECTION 2  
DATA ANALYSIS PLAN

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## SECTION 2

### DATA ANALYSIS PLAN

#### 2.1 PLAN FORMULATION

One of the early contractual requirements for an ERTS-1 investigation was the submittal of a Data Analysis Plan for NASA monitorial review. The DAP for this experiment was submitted in December 1972 and approved in March 1973.

At the time the specific plan was formulated, an attempt was made to exercise all the known elements or functions spelled out in the plan using ERTS imagery from two passes on hand. It was anticipated that the means to analyze data in the form of computer compatible tapes would be available to the team. The project data sources thus could be categorized as in Figure 2-1.

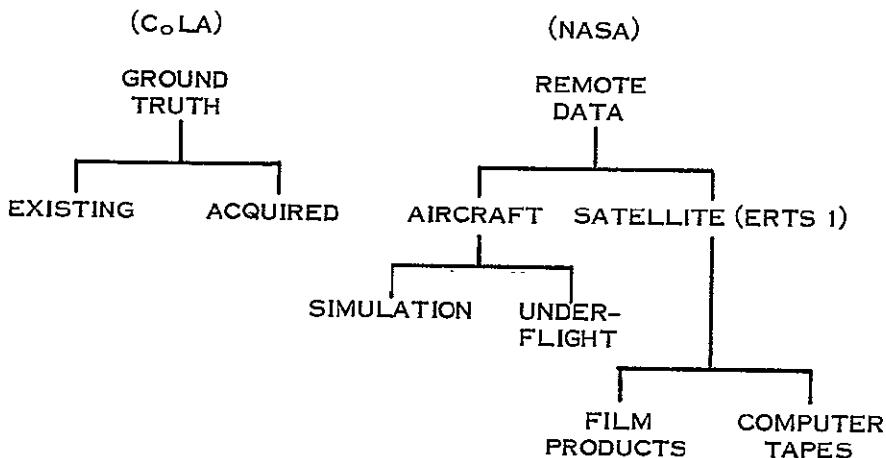


Figure 2-1. Project Data Sources .

The analysis plan was developed with a view to meeting the objectives of the investigation within the resources at the team's disposal. As the experiment progressed, there was much additional support received by the team which enabled the investigators to proceed beyond the originally proposed scope of the analysis plan. Thus, secondary users across the entire test site (See Section 4 for details) provided much valuable ground truth supplementing that acquired by the primary user, the County of Los Angeles Regional Planning Commission. In the realm of remote data, a significant amount of non-standard film products were made available primarily by the General Electric Photoengineering Laboratory and secondarily by the Hughes Aircraft Company both with respect to scale as well as band-filter or color assignments different from the NASA Data Processing Facility products. The wealth of film inputs thus available for this investigation is seen from Figure 2-2. All the computer compatible tapes came only from NASA Goddard.

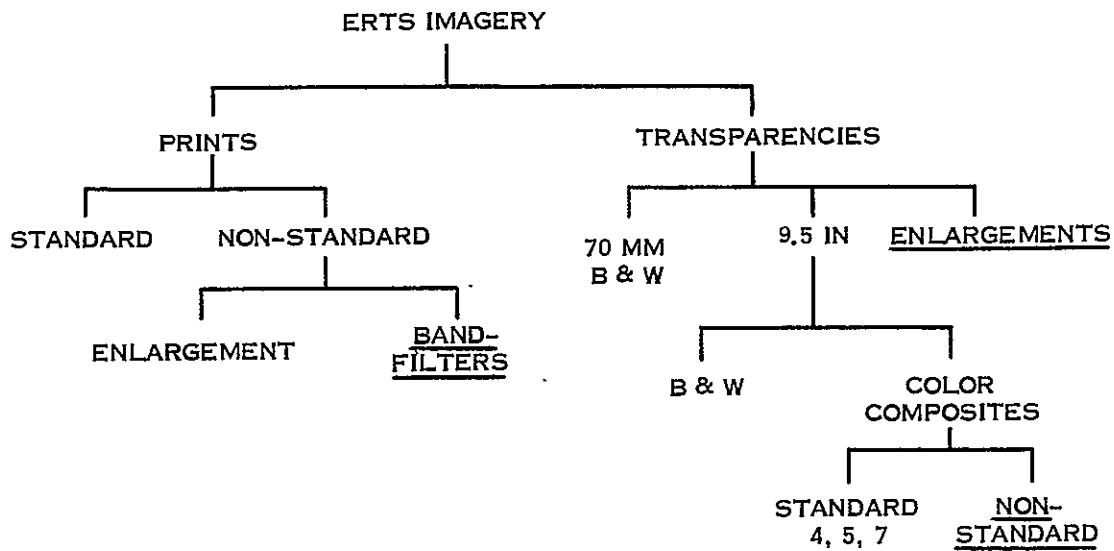


Figure 2-2. Los Angeles Test Site Film Product Inputs (Non-NASA Items are Underlined)

One of the major input products that had been anticipated by the team with much expectation was the Return Beam Vidicon (RBV) data.

The operation of the RBV on ERTS-1 had to be discontinued before the first pass over Los Angeles which took place on August 10, 1972. It seems the team would have to obtain LANDSAT 2 RBV data over the (COLAGE Test Site, SR124).

## 2.2 ANALYSIS IMPLEMENTATION

The Data Analysis Plan submitted to NASA included specific and detailed discussion of the proposed implementation procedure which itself had been preliminarily exercised with the earlier ERTS products then on hand. In this final project report, the details of the tools/systems used for analysis, as well as the techniques developed/applied, would be more appropriately taken up preceding the discussion of their application to arrive at the desired results themselves. Accordingly, only an overview of the implementation approach will be given here. Also certain exploratory or backup analysis "tools" that had been alluded to in the plan, but were not required to be followed through, will be mentioned here primarily for the sake of completeness.

In implementing both the manual photointerpretation and machine-aided data analysis methods proposed in the plan, there was an almost natural division of labor between the County of Los Angeles and General Electric-OVAAC8 team members (East/West Coasts) as indicated in Figure 2-3. Of course the very interactive nature not only of the tools of analysis used, viz, the General Electric Multispectral Information Extraction System (GEMS) and its successor the IMAGE 100, but also of the analysis approach itself by the team members resulted in considerable "cross-operation"; the County and OVAAC8 planners, participated in hands-on electronic analyses while the GE and OVAAC8 analysts evaluating the photointerpretation overlays against the raw data displayed photographically and electronically.

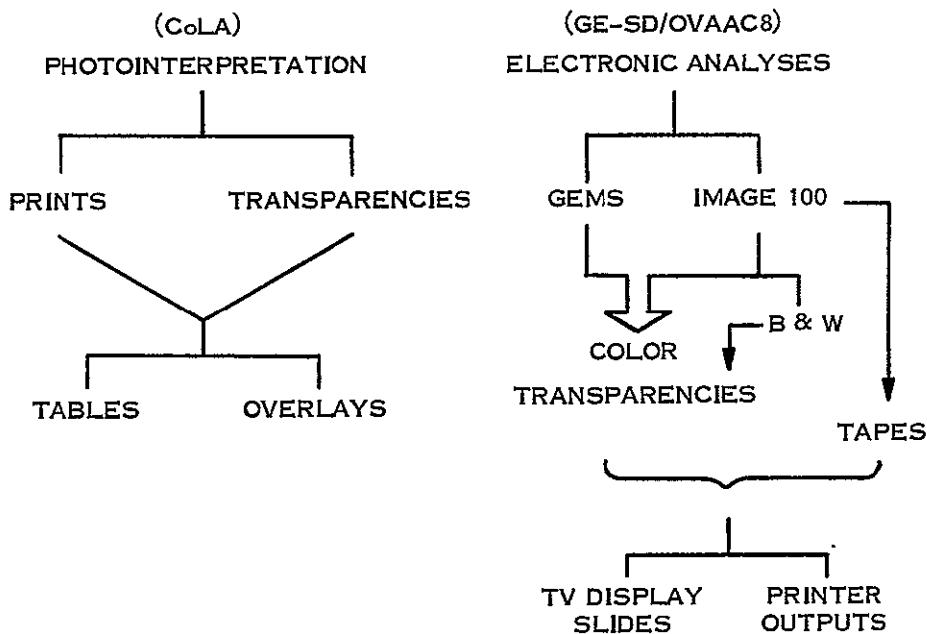


Figure 2-3. Analysis Functional Flow and Interim Products

Here it might be mentioned that the GE-OVAAC8 team members experimented briefly with two other machine analysis tools/techniques both owing to the courtesy of NASA Goddard personnel with facilities at the GSFC: 1.) An I<sup>2</sup>S viewer, an optical device for on-line color compositing/photointerpretation, with 70 MM film transparency input; 2.) The LARS System via a remote terminal, a general purpose digital computer software package with compatible tapes input.

Another brief diversion attempted was to develop the Diazo Composite Transparencies. Since these were contemplated for use on the GEMS, the difficulties in achieving sufficiently precise registration, as well as their total density variability, presented serious problems and did not warrant further effort in this area. The NASA standard and GE non-standard transparencies were determined to be of minimum requisite quality spatially and spectrally for input to any machine-analysis, at least on the GEMS and the IMAGE 100.

One methodology "issue" that had been briefly touched upon in the original presentation of the Data Analysis Plan and which was elaborated upon in subsequent reports as well as presentations, should be reviewed here: the two complementary starting points for computerized analysis of multispectral data, usually described as the supervised and the unsupervised learning approaches. Table 2-1 summarizes their complementary characteristics.

Table 2-1. Complementary Characteristics of Machine Analysis Learning Techniques

Supervised Approach	Unsupervised Approach
<ul style="list-style-type: none"> <li>● A Priori</li> <li>● Ground Data Based</li> <li>● Specific/Local</li> <li>● Spatial Theme Synthetic</li> <li>● Monst thematic</li> </ul>	<ul style="list-style-type: none"> <li>● A Posteriori</li> <li>● Scene Content Derived</li> <li>● Generic/Global</li> <li>● Spectral Cluster Analytic</li> <li>● Hetero/Multi-thematic</li> </ul>

Thus, the "findings" from the actual application of the data analysis plan on the GEMS through the early pre-submission phase, could be characterized as follows:

- In an a priori approach, the investigator begin with inputs (for "training") while such information has to be derived (through "bootstrapping") in the a posteriori approach.
- The user has a starting point vis-a-vis ground truth in the ground data based approach, whereas the user begins "scrutinizing" an image in the scene content derived method with a view to arriving at plausible training sites.
- Specific/local and generic/global apply in a geographic sense to both geometric and spectral space/features.
- A theme is synthesized sequentially based on a relatively homogeneous geometric criteria in the spatial theme synthetic method of analysis. In the spectral cluster analytic approach, the inter-relationships of a group of themes are emphasized via spectral criteria.

Subsequent analyses throughout the investigation not only used both of these complementary approach, depending upon their suitability to the application being studied, but also often "hybridized" them in an iterative fashion to yield more comprehensive results in a cost-effective manner.

Finally, apart from RBV data, MSS precession or scene corrected data also was not proposed to be analyzed to any extent in this investigation. Resources could not be provided for these nor for a vigorous machine aided, quantitative comparison between transparencies and tapes for a given scene though IMAGE 100 offers a unique tool to do so.

### **SECTION 3**

#### **PHOTOINTERPRETATION STUDIES WITH ERTS FILM PRODUCTS**

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## SECTION 3

### PHOTOINTERPRETATION STUDIES WITH ERTS FILM PRODUCTS

#### 3.1 BACKGROUND OBSERVATIONS

Two methods were used to analyze ERTS imagery of the Greater Los Angeles area in the present study: photointerpretation through the use of standard techniques, and innovative machine analysis. The latter topic is developed in Section 4, and the more conventional photointerpretation is treated in this section.

Photointerpretation has been developed over several years especially since repetitive imagery of any region can now be returned from scheduled flights of reconnaissance aircraft. Within constraints of local weather conditions and cloud cover, these flights have produced photographs or transparencies of a region not only in the visible light spectrum, but also in the infrared region which has increased the amount of data available for analysis.

Standard techniques of photo analysis have thus been established that put good lenses, highly accurate calibration facilities, and advanced methods of photo projection at the disposal of those specialized in the art of interpreting regional photography. But these devices are only aids. Derivation of the maximum amount of data is dependent on the skill of the interpreter and his familiarity with the region under study.

Photographic interpretation is a deductive process. Features that can be recognized and identified directly lead the photointerpreter to the identification and location of other features in the terrain under consideration. Even though all aspects of a terrain are complexly intertwined, the photointerpreter must start some place. He cannot consider drainage, landform, vegetation, and man-made features simultaneously; he must start with one feature, or groups of features, and go on to the others, integrating each facet of the terrain as he proceeds.

The deductive process which is photographic interpretation requires consideration of the following elements:

Shape. The shape or form of some objects is so distinctive that their images may be identified solely from this criteria. Marinas, reservoirs, and agriculture fields are examples.

Size. In many cases, length, width, height, area, and volume are essential to accurate and complete interpretation.

Tone. Different objects reflect and emit different amounts and wavelengths of energy. These differences are recorded as tonal, color, or density variations.

Shadow. Shadows can help or hinder the interpreter since they reveal or hide some details.

Pattern. Pattern, or repetition, is characteristic of many man-made objects and of some natural features.

Texture. The visual impressions of roughness or smoothness created by some images are often valuable clues in interpretation.

Site. The location of objects with respect to terrain features or other objects is often helpful.

Association. Some objects are commonly associated with other objects that tend to indicate or confirm the other.

Resolution. Resolution always places a practical limit on interpretation. Some objects are too small, or otherwise lacking, to form a distinct image.

Interpretation of standard ERTS images of the Los Angeles area was conducted at the County by the Co-Investigator and Test Site Coordinator. To develop further information beyond the NASA ERTS images, non-standard imagery was made available. Images were processed in different spectral band combinations which enhanced details and added to the fund of data that could be derived. The standard ERTS scale of 1:1,000,000 was often changed to allow interpretation at various scales.

### 3.2 TOPICAL ANALYSES OF STANDARD FRAMES

While the task of outlining the areas of interest to the County planners, with a view to assessing the availability/need for acquisition of the necessary ground truth, had been initiated at the outset of the project, this activity was best carried out with the actual ERTS imagery becoming available to the COLAGE team. The novelty of the data justified this procedure.

The black and white transparencies (both the 70mm and the 9.5-inch formats) usually were received much earlier than the color composites. Preliminary analysis was usually begun with the black and whites but the principal effort was spent on the color products.

A convenient device to record, summarize/annotate and transmit the results of photointerpretation was in the form of an "overlay". For each topic of interest to the County planners, a line drawing was made by tracing over the film product at a scale of 1:1,000,000, and fully annotated/commented upon. The annotation lists primarily were what NASA had earlier in the ERTS mission characterized as Image Descriptors, entered onto the respective forms. However, the spatial reference an overlay provides is an essential characteristics for local ERTS scenes usage. An example of an image description is shown in Table 3-2.

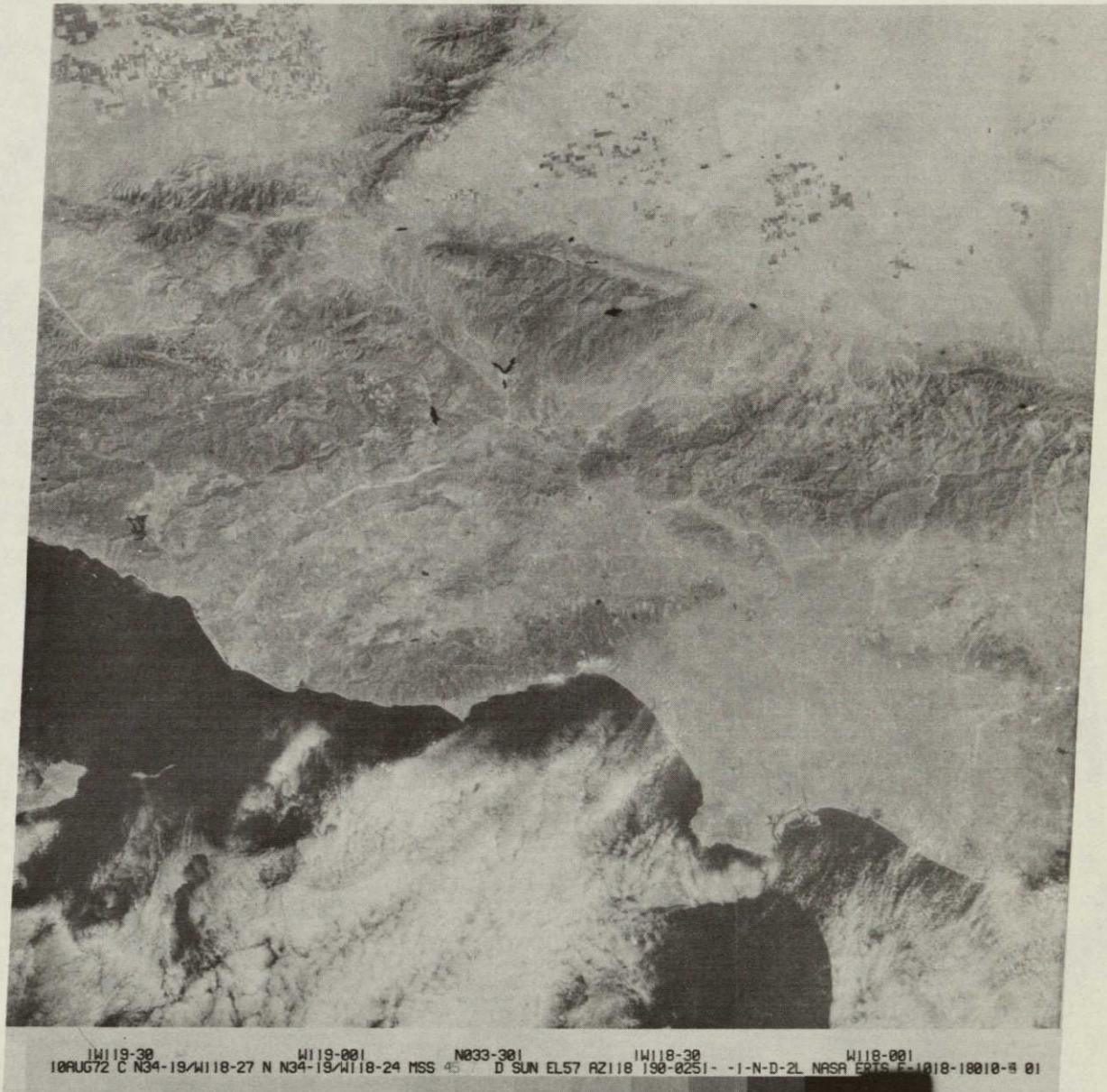
The "topical" overlays phase of the COLAGE investigation covered the earliest set of scenes requested and procured:

1. Cycle 1: Aug. 10, 1972:  
1018 - 18010; Figure 3-1
2. Cycle 5: Oct. 21, 1972:  
1090 - 18012; Figure 3-2
3. Cycle 8: Dec. 14, 1972:  
1144 - 18015; Figure 3-3

A chronological discussion of the photointerpretive results, summarized into overlays, was made in the Type I reports on this project. It indicated both the priority of interests on the County Co-Investigators' part as well as the feasibility of extracting the respective information visually. Here, it is best to present the summary topically grouped:

1. Regional Interpretative Overlays
2. Urban Areal Overlays

The full set of overlays were issued in a "COLAGE Mid-Project Presentation" book. Only selected topics will be highlighted here.



IW119-30      IW119-001      N033-301      IW118-30      W118-001  
10AUG72 C N34-19/W118-27 N N34-19/W118-24 MSS 45      D SUN EL57 R2118 198-0251- -I-N-D-2L NASA ERIS F-1018-18010-5 01

Figure 3-1. Cycle 1, August 10, 1972

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W118-00  
21OCT72 C N34-33/W118-24 N N34-31/W118-19 MSS W118-00  
D SUN EL39 RZ148 190-1255-G-1-N-D-2L NASA ERTS E-1080-18012-4 01

Figure 3-2. Cycle 5, October 21, 1972



Figure 3-3. Cycle 8, December 14, 1972

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An overlay of the County boundary in relation to the imagery is shown in Figure 3-4.

### 3.2.1 REGIONAL INTERPRETATIVE OVERLAYS

The synopticity and the multispectrality of ERTS data are brought to bear fully at the regional level. Table 3-1 gives an idea of the comprehensiveness of the topics covered. A few specific overlays are discussed further.

#### 3.2.1.1 Geology

An extremely varied geology undergrids the County of Los Angeles. Metamorphic rocks and consolidated sedimentary formations stand out as hills and mountains. Soft sedimentary formats and consolidated sediments are manifested as plains and valleys.

A vast, complex active fault system, present in the bedrock foundations of the County, poses a very present danger to cataclysmic earthquakes. Quake danger is not confined to proximity with active faults. The poorly consolidated sediments of the valleys and plains are more prone to quake movement than hardrock areas of the mountains and hills. An overlay of the major faults and fracture zones is shown in Figure 3-5, derived from the December 14, 1972 ERTS Scene 1144-18015.

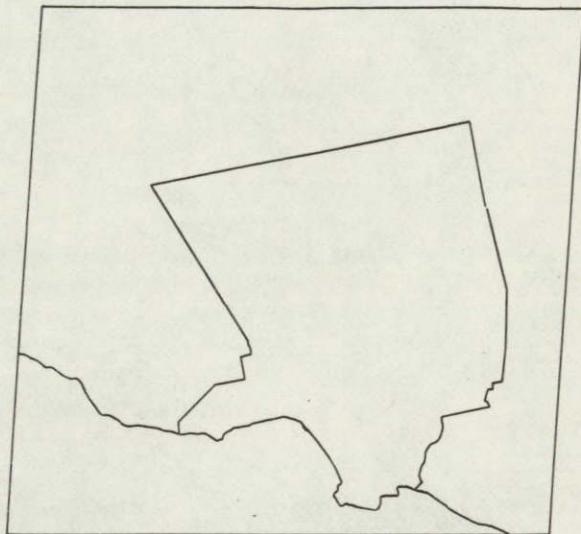


Figure 3-4. County Boundary Overlay  
Frame 1144 - 18015, 14 December 1972

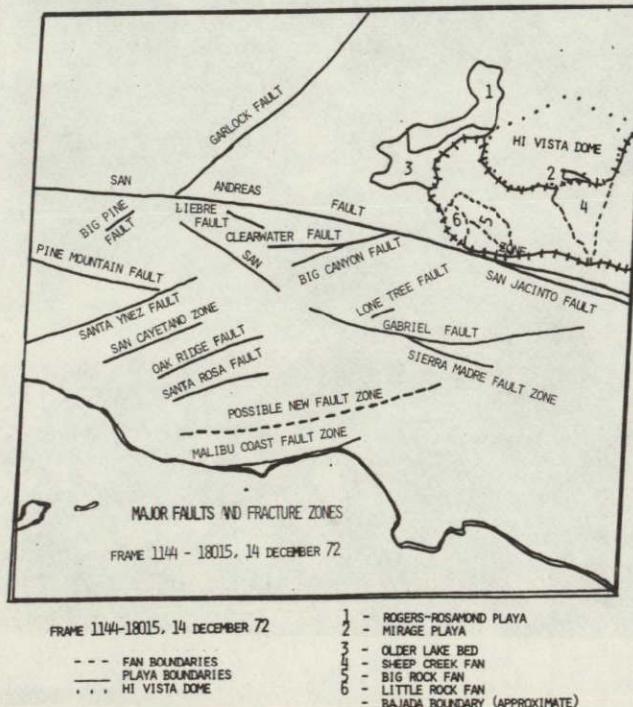


Figure 3-5. Major Faults and Fracture Zones (Scene Frame 1144-18015, 14 December 1972)

Table 3-1. Regional Overlays Topics

Serial No.	Topic/Theme	Features/Descriptors	
		Total No.	Cycle
1	Major Natural Provinces	7	5
2	Major Regions	5	1
3	(Planning) Sub-Regions	11	1
4	Selected Topographic Features	177	5
5	Major Faults and Fracture Zones	17	8
6	Selected Minor Landforms	7	8
7	Streams	84	5
8	Reservoirs and Lakes	47	1
9	Snow Cover and Fog	18	8
10	Grass Growth	9	8
11	Brush Fire Burns	4 + 2 = 6	1 + 5*
12	Major Agricultural Areas	20	5

\*Bare forest fire occurred between the first and fifth cycles. Malibu fire burn, even though it occurred in 1970, was not as distinctly visible in Cycle 1 as it was in Cycle 5.

Slides and slope failures are concentrated in mountains and hills. Significant concentrations of slides are in the Puente, San Jose, and Palos Verdes Hills, the south side of the Santa Monica Mountains, the front ranges of the San Gabriel Mountains, and the Middle Santa Clara Valley around Newhall and Saugus.

A close examination of the ERTS Scene 1144-18015 (Figure 3-3), as processed by the GE-Beltsville Photo Engineering Laboratory, has led to the tentative identification of a major new fault in the Santa Monica Mountains.

The alluvial fans such as are shown in Figure 3-4, usually are sources of such building materials as sand, gravel and rock. Playas are usually sources of salt. The dark tones within the playas seen (Figure 3-3) in the December 14, 1972 image (bands 4, 5, 6) have been pointed out by the County hydrologists as an indication of high water table and are being evaluated for potential search of ground water.

### 3.2.1.1 Hydrology

#### 3.2.1.1.1 Streams

The County has two major natural drainage systems; one draining to the ocean and the other to closed desert basins. All the coastal lowlands and most of the mountains drain to the ocean. Figure 3-6 is a reproduction of the overlay made from the ERTS Scene of October 21, 1972, 1090-18012. Arrows on the streams indicate the direction of drainage. The Northern margins of the mountains and Antelope Valley drain to Rosamond Playa. Streams get smaller downstream and normally do not flow most of the year outside the mountains. Stream channels on deserts and coastal lowlands are shallow and poorly defined, which compounds the flood threat caused by concentration of winter rains in the mountains. The

list in Figure 3-6 is the key in the fashion of the ERTS Image Descriptor Form which is presented as Table 3-2.

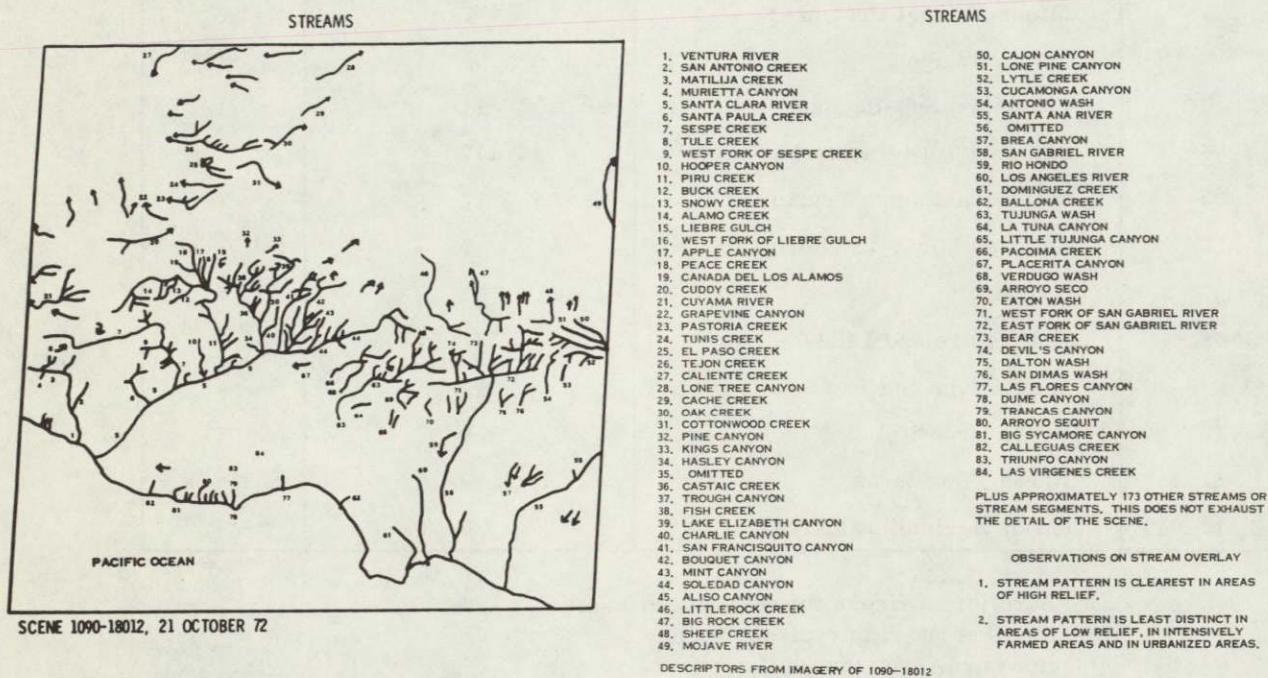


Figure 3-6. Streams (Frame 1090-18012, 21 October 1972)

Table 3-2. ERTS Image Descriptor Form for "Streams" of Figure 3-6.

ERTS IMAGE DESCRIPTOR FORM  
(See Instructions on Back)

DATE _____	FREQUENTLY USED DESCRIPTORS*			NOT FOR USE ONLY
PRINCIPAL INVESTIGATOR _____	Streams	Rivers	Creeks	D _____ N _____ ID _____
GSFC _____	Canyon	Wash	Gulch	
ORGANIZATION _____				
PRODUCT ID (INCLUDE BAND AND PRODUCT)		FREQUENTLY USED DESCRIPTORS*		DESCRIPTORS
109-18012 (4, 5, 7)		Streams	Rivers	Creeks
		Canyon	Wash	Gulch
<small>*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. IF OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN.</small>				
<small>MAIL TO ERTS USER SERVICES CODE 563 BLDG 23 ROOM E413 NASA GSFC GREENBELT, MD. 20771 301-902-5406</small>				

\* For streams of Figure 3-6.

GSFC 57-2 (7/72)

### 3.2.1.1.2 Snow Cover

Analysis of snow cover is of interest not only as an input to the water resources data base of the County, but also for recreational planning. A single source overview of snow cover was not available until the ERTS scene, shown in Figure 3-7, was made available. Snow covered areas in the scene fall in a wide range of elevations:

Antelope Valley	3,000 ft
Desert Mountain Foothills	4,000 ft
Central Mountains	7,500 to 10,000 ft

Fog in this scene appears as a strato cumulus structure, while snow can be seen to be smooth in texture.

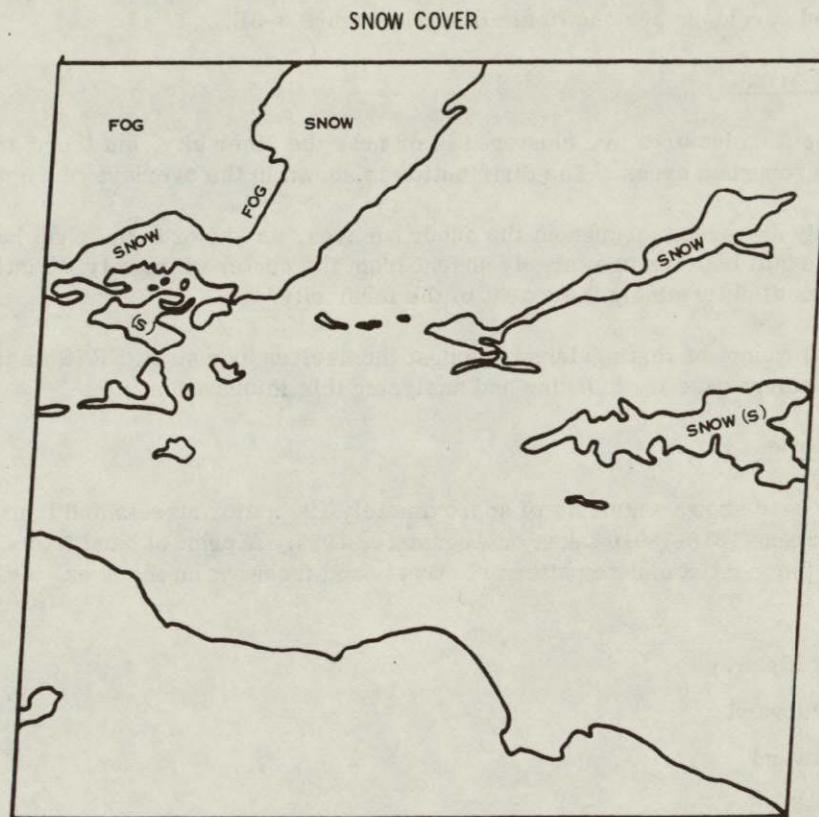


Figure 3-7. Snow Cover (Frame 1144-18015, 14 December 1972)

### 3.2.2 URBAN AREAL OVERLAYS

A comparison of ERTS imagery from several passes show the vast metropolitan Los Angeles urban region that covers some 1500 square miles of LA and adjacent counties. This sweeping overview enables the observer to see how the city relates to the surrounding region, and how the metropolitan area is located in relation to the great agricultural districts. Also visible is the relation of metropolitan Los Angeles to the neighboring urban areas in Southern California (see Figure 3-1, 3-2 and 3-3).

The distinctive feature of the Los Angeles Metropolitan area that can be discerned from an ERTS image is its compact and contiguous character, with very little outlying urban sprawl. This characteristic of Los Angeles distinguishes it sharply from other U.S. urban areas, especially the older eastern cities. Such a view of Los Angeles is in contrast to the conventional concept of the City of Los Angeles being the epitome of urban sprawl in the U.S.

The overlay of Figure 3-8 shows the major urban areas around metropolitan Los Angeles, and the shape of the central city. It illustrates how the central city is situated in relation to the metropolitan edges and higher quality residential areas. Major urban open spaces are identified (such as parks and golf courses), the larger industrial areas, the regional business districts and shopping centers, the prominent streets and highway patterns can be identified by the experienced observer. Thus, analysis of ERTS imagery can provide inputs to the urban planning data base.

### 3.2.2.1 Commercial and Industrial Complexes

The X-shaped structure of the inner core of Los Angeles urban region is readily visible as the bluish-gray area in most ERTS scenes to the casual observer. The finer details within this structure require a more experienced interpreter who is also knowledgeable about the city and its vicinity. The commercial centers, including shopping centers and strip commercial areas thus discerned are shown in Figure 3-9A. The industrial districts and corridors are shown similarly in Figure 3-9B.

### 3.2.2.2 Recreational Areas

Major parks in the Los Angeles area are clustered in or near the inner city, but there are relatively few large parks in the suburban areas. The distribution is shown in the overlays of Figure 3-9.

Golf courses are widely dispersed throughout the suburban area, as shown in the right hand illustration of Figure 3-10. These golf courses are largely absent from the center of the city. Distribution of the golf course is one index of determining the extent of the inner city.

Parks and golf courses cannot be distinguished amongst themselves/*per se* on ERTS imagery but the images provide a convenient base for indexing and analyzing this information.

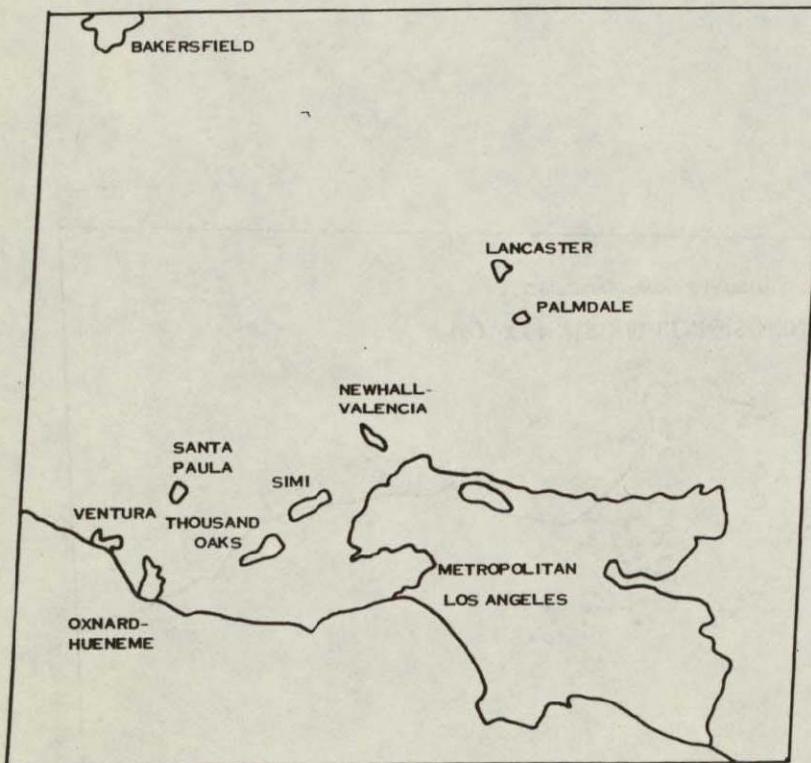
### 3.2.2.3 Streets and Freeways

The overlay of Figure 3-10 shows segments of approximately 190 major streets and freeways that can be identified in ERTS Scene 1018-18010 taken on August 10, 1972. A print of band 7 was chosen because it appeared to contain the most complete pattern of streets and freeways in the area. Only a few thoroughfares are referenced:

1. Pacific Coast Highway
2. Wilshire Boulevard
3. Foothill Boulevard
4. San Fernando Road
5. Antelope Valley Freeway
6. Sierra Highway
7. Ventura Freeway
8. San Diego Freeway
9. Valley Boulevard
10. Golden State Freeway
11. Wittier Boulevard
12. Telegraph Road

The street pattern provides one basis for dividing the urban areas into suburban regions for more detailed planning studies.

MAJOR URBAN AREAS



21 OCTOBER 72, NASA ERTS 1090-18012

METROPOLITAN LOS ANGELES URBAN STRUCTURE I

1. CENTRAL LOS ANGELES
2. CENTRAL LONG BEACH
3. PALOS VERDES ESTATES
4. LA HABRA HEIGHTS
5. COVINA HILLS
6. SAN MARINO
7. FLINTRIDGE
8. SHERMAN OAKS - ENCINO
9. HANCOCK-FREMONT PARK
10. HILL CREST
11. BEVERLY-HOLMBY HILLS
12. BEL AIR-BRENTWOOD
13. EAST SANTA MONICA MOUNTAINS
14. VERDUGO MOUNTAINS (A NON URBAN AREA)
15. OTHER UNDIFFERENTIATED URBAN AREAS

DESCRIPTORS FROM IMAGERY OF 1090-18012



FRAME 1090-18012, 21 OCTOBER 72

Figure 3-8. Relationships of Urban Areas Around and Within Metropolitan Los Angeles

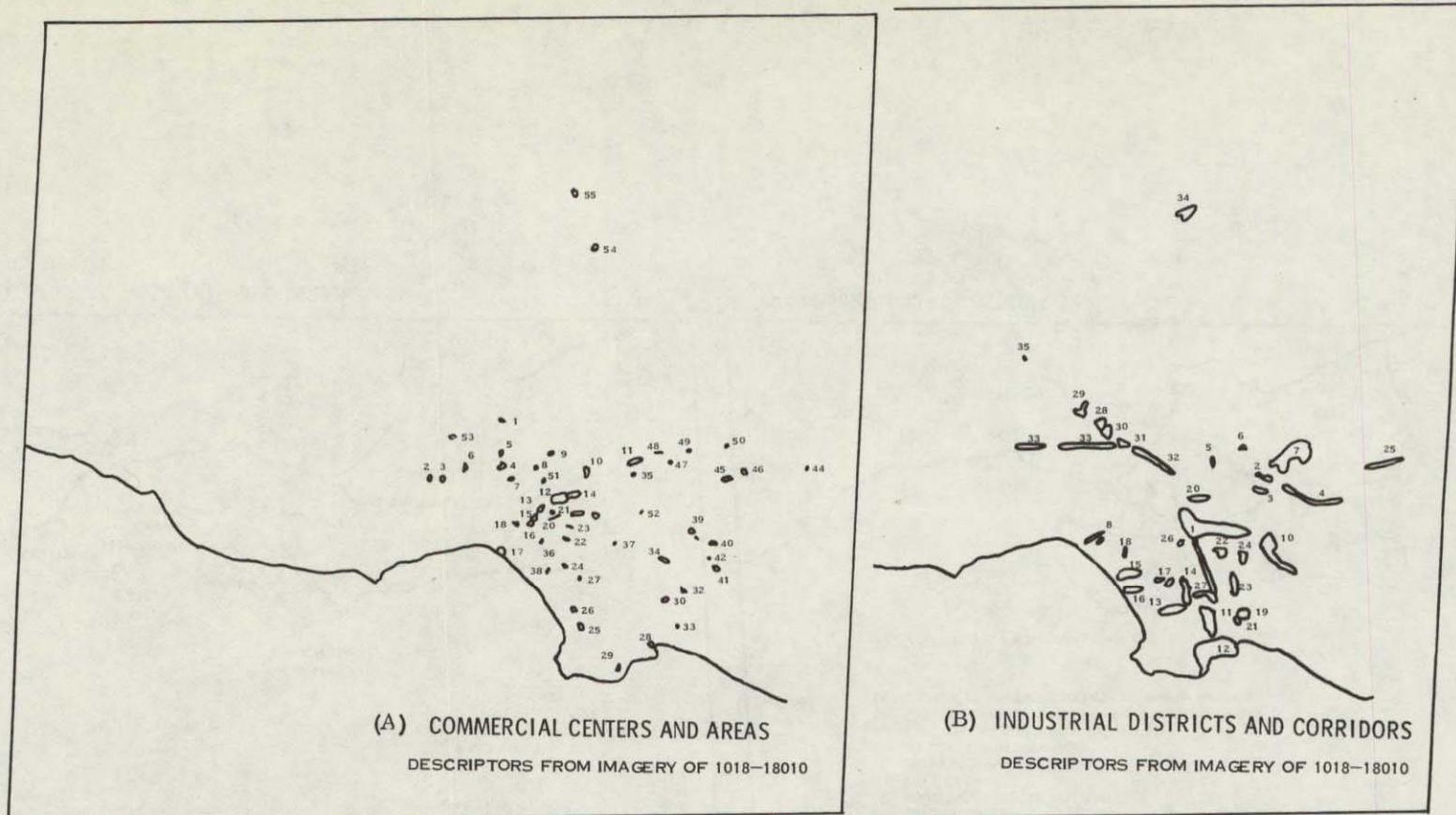


Figure 3-9. Commercial and Industrial Complexes



Figure 3-10. Distribution of Parks and Gold Courses

The broken San Gabriel Valley grid may, in part, reflect the effects of political fragmentation of the area among more than a score of incorporated cities while the pronounced, fine-textured grid of San Fernando Valley may, in part, reflect its political unification in the City of Los Angeles.

### 3.2.2.4 Grading and New Construction Sites

The ability to detect new grading and construction sites will permit the rate, extent and direction of urban fringe growth to be monitored. Grading and new construction sites have only partially verified in the west central sector of the overlay in Figure 3-11. Several dozen additional sites can be verified through further analysis.

## 3.3 SEASONAL INSIGHTS FROM STANDARD IMAGERY

Even though the primary emphasis in the previous discussion was topical, the 1972 frames in Figures 3-1, 3-2, 3-3 respectively also provided certain seasonal characteristics of the Los Angeles area rather dramatically and for the first time with data produced under excellent control. The 1972 late summer, fall and early winter scene analyses were continued into the more explicitly seasonal observations of the 1973 scenes discussed here.

### 3.3.1 SPRING

#### 3.3.1.1 ERTS Scene 1234-18021

The subject of these comments is a false color (bands 4, 5 and 7) print of ERTS 1 Scene 1234-18021, dated March 14, 1973 (Figure 3-12). The scene is cloud free except for a limited area of the Northeastern San Gabriel Mountains. There are patch clouds in the Mt. Pinos area and in the southern Sierra Nevada ranges. Higher mountain areas (estimated 5,000 ft and above) are snow covered. Snow is prominent in the Mt. Pinos-Frazier Mountain district, the San Gabriel Mountains and the Tehachapi-Southern Sierra Nevada Mountains.

Vegetation is very prominent. Grassland areas are intensely red. Especially prominent is the crescent of grassland around the hilly margins of the San Joaquin Valley. Likewise, grassland areas mostly in Ventura County west of the San Fernando Valley are very red. Low lying sagebrush and chapparal covered hills near the sea also show vigorous red tones. They are generally less intensely red than grasslands. Higher mountains exhibit light brown to dark brown tones. In these areas vegetation may still be largely dormant due to winter conditions which still persist at a higher elevations (estimated at 3,000 ft and above). Faint red and orange tones are visible in desert areas. These tones are more prominent in elevated hills and plains, but are largely absent from playas, old lake beds and porous alluvial fans. Irrigated agricultural lands are less well defined than in summer because vigorous vegetation growth on adjacent non-irrigated lands tends to blend with cultivated fields. However, dry farmed fields in the Western Antelope Valley of Los Angeles County have been made visible (apparently by tillage patterns) in contrast with adjacent irrigated and/or natural plant growth. The pattern of North-South windbreaks is faintly visible in a citrus growing area of the Oxnard Plain.

Contrast imparted by spring vegetation growth more sharply define the edges of urban areas than was the case with summer and autumn imagery. The urban vegetation pattern contains much detail. Large high use intensity urban districts with little or no vegetation, are more sharply outlined than in summer imagery. However, the urban street pattern is less visible in comparison with summer imagery. There is less contrast between urban residential areas. Apparently, this stems from the fact that vegetation in all areas grows as a result of winter rainfall, but in summer only vegetation in higher income areas receives sufficient care to maintain a healthy condition.

Urban open spaces are not as easy to distinguish in this scene. This is due to the fact that natural growth on vacant lands also shows as bright red similar to that displayed by formal open spaces (parks and golf courses). Thus comparison of summer and spring imagery may permit large formal public open spaces to be distinguished from major plots of undeveloped or vacant land in urban areas.

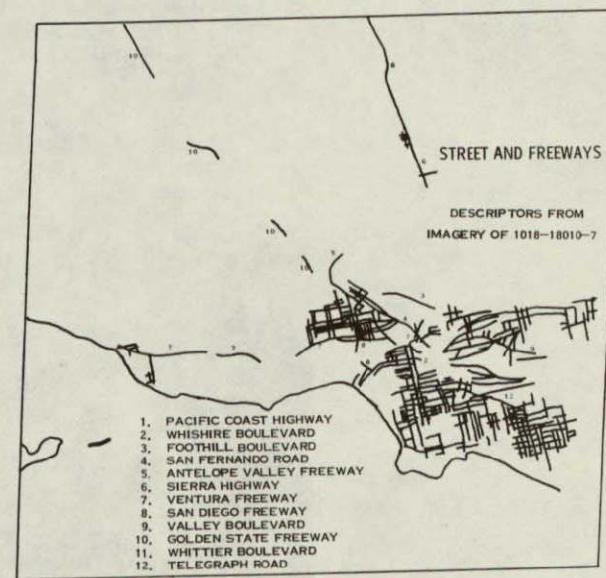
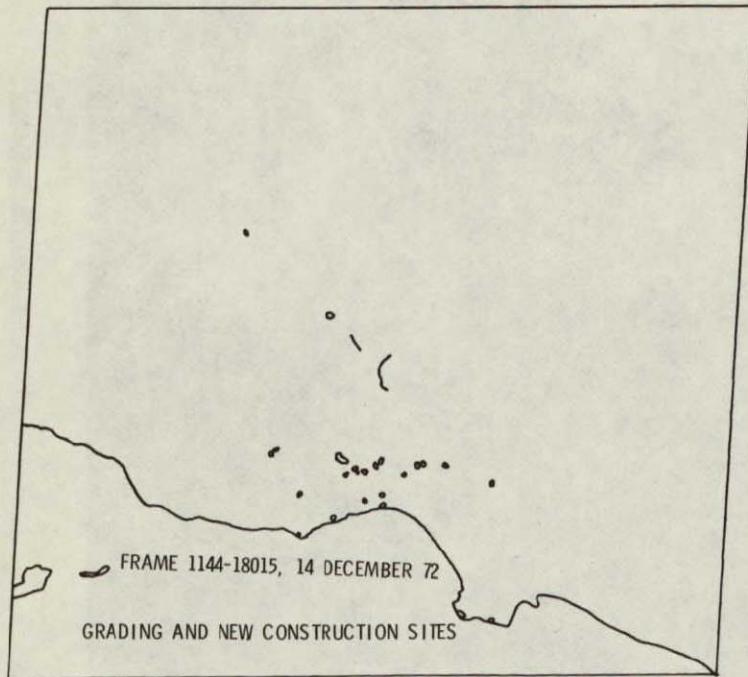


Figure 3-11. Grading and New Construction Sites (A), Streets and Freeways (B)



Figure 3-12. False Color Image of Los Angeles, Scene 1234-18021, March 14, 1973

As in other scenes described previously, much terrain detail is visible. Detail appears somewhat less than in winter (December) imagery. This may stem from higher sun angle and less shadow in March imagery. Considerable drainage detail is also visible. The larger, wider natural and improved stream channels can be seen and distinguished from each other. Water is visible in a number of channels which did not have surface water in summer imagery. Reservoirs and lakes are still clearly visible but are not as sharply defined as in summer imagery because of less contrast. Water spreading grounds, used to percolate winter stream runoff ponded into the underground water basins, have been made visible by the presence of ponded surface water. Spreading grounds are not as prominent in summer imagery. In the coastal waters, a large light colored area is visible off the Oxnard Plain, extending down coast at least to the Pt. Dume area. This is apparently a result on storm generated runoff largely from the Santa Clara and Ventura Rivers. Near Long Beach and San Pedro, the breakwater of Los Angeles - Long Beach Harbors is faintly visible. Four artificial islands used for oil drilling are visible off Long Beach. In desert areas, dark tones on playas indicate the presence of winter runoff which has pooled or at least wetted these normally dry lake beds. Large coastal wetlands areas can be distinguished by tone, shape and location.

Considerable landform and geological detail can be seen. Major fault lines are visible. Large alluvial fans are well defined in Antelope Valley, and branching distributaries are visible on their surface. Old playas and lakebeds are clearly defined and their surfaces exhibit much more detail than was the case with summer imagery.

Major linear features (aqueducts and newly constructed freeways) stand out clearly. Large new construction sites on the urban fringe stand out much more clearly than in summer imagery because their freshly graded surfaces contrast sharply with the lush spring vegetation of adjacent lands.

Sandy beaches are clearly visible from their light hues. Rocky coastlines may be inferred by association with adjoining hilly areas together with the absence of sandy beaches. Harbors and marinas are visible from their pattern of major piers and channels. The runways of major airports can be seen along with vegetated areas along runway perimeters.

The pattern of major streets is visible but is less clear than in summer imagery. Numerous large buildings and structures can be seen in urban areas. These include large industrial and commercial buildings and stadia. Several large railway yards are visible by their dark tones, linear shapes and association with high intensity land use districts. Some high intensity use clusters are visible but less so than in the case of December imagery when visibility is enhanced by the presence of more shadow from medium and high rise structures.

The above comments indicate that this imagery contains much data. The data content is enhanced by comparison with imagery taken in other seasons.

### 3.3.1.2 ERTS Scene 1288-18020

The subject of these comments is a standard 9 inch by 9 inch, false color composite print (bands 4, 5 and 7) of ERTS Image 1288-18020, dated May 7, 1973. See Figure 3-13. Considerable cloud cover is visible over the southeastern one-third of the scene which obscures portions of the Los Angeles Metropolitan area and Antelope Valley.

As in imagery previously described, there is much detail on topography, landforms, drainage patterns, water features, vegetation, geology, urban street patterns, major linear features (aqueducts and new freeways), large buildings, and agricultural patterns.

The most outstanding change from March 1973 imagery is the fading intensity of the reds as a result of the onset of the dry summer season. Elevated desert plains and low-lying foothills have changed from a bright red in March to tan in May. This permits a sharp definition of irrigated farm fields in May imagery. In Antelope Valley fields, strip cropping patterns are clearly visible.

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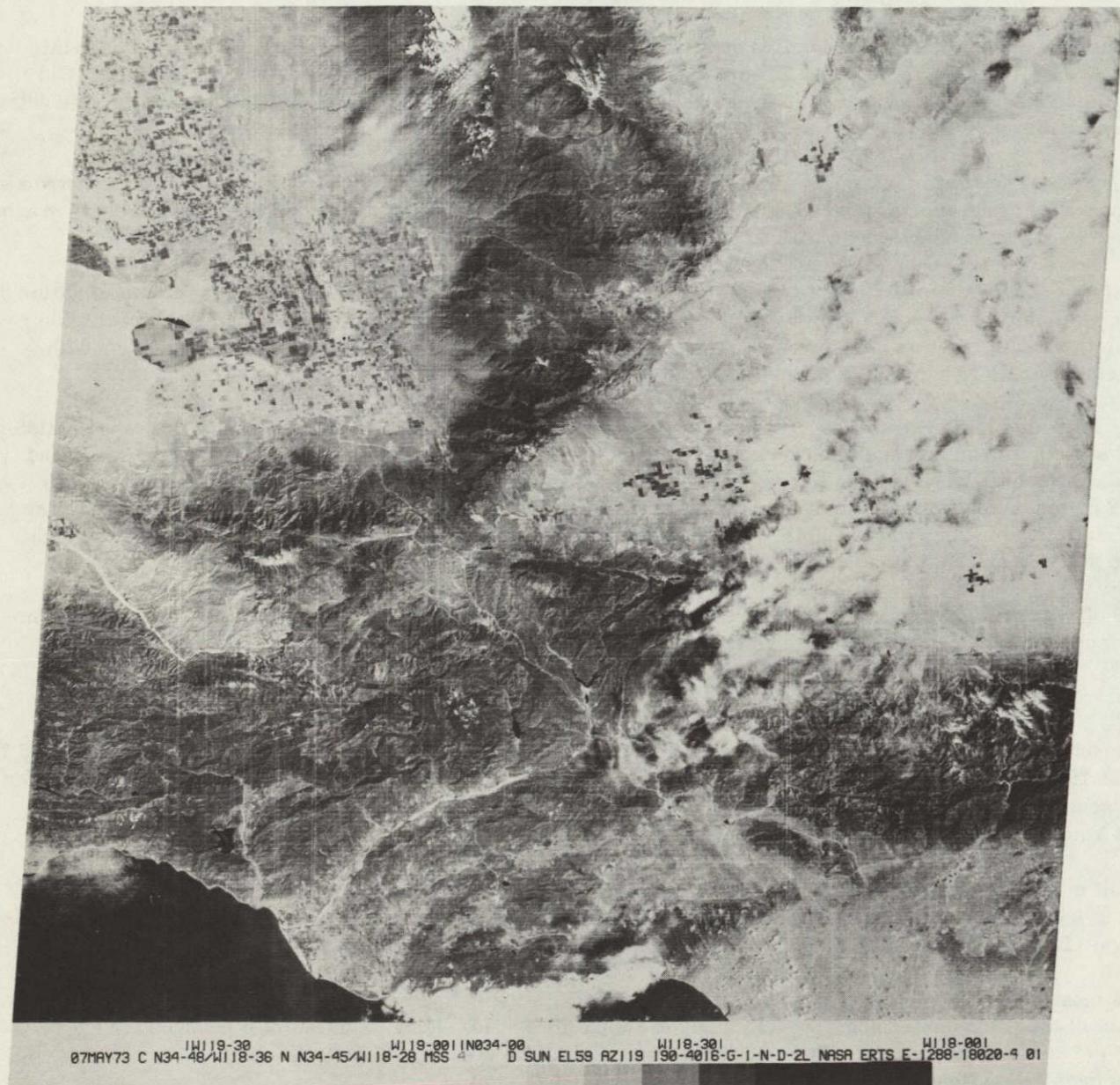


Figure 3-13. False Color Image of Los Angeles, Scene 1288-18020, May 7, 1973

Snow has disappeared from all but the very highest mountain peaks. Higher mountain areas are a brighter red than in March. Coniferous woodlands in the Mt. Pinos-Frazier Mountain areas are a brownish red in contrast with surrounding brighter red areas.

Because of stronger contrast, water bodies are more clearly defined than in winter imagery. The same is true for larger fire areas.

### 3.3.2 SUMMER (Figure 3-14)

The subject imagery is a 9 inch by 9 inch false color (bands 4, 5 and 7) positive transparency of ERTS-1 Scene 1324-18014 dated June 12, 1973. Cloud cover obscures the coastal margins of metropolitan Los Angeles. As in other imagery of this locality a great range of detail is available. Vegetation in higher mountains and hills is generally manifested by bright red hues. Even areas that had shown an late spring imagery in brownish hues now exhibit a brighter red color. Vegetation in foothill areas and high desert plains which had displayed intensely red hues in March now manifests tan hues and suggests a growing wild fire hazard. Scars left by recent fires are clearly defined. Irrigated farm districts and fields are clearly defined in all areas except the Oxnard Plain where coastal hills on the margins of farm fields are still manifesting bright red hues which are difficult to distinguish from the fine grained field pattern.

Terrain details are reasonably sharp as are the drainage patterns. Reservoirs and lakes are sharply defined in contrast with surrounding pale reds and tans. Major drainage channels are well defined.

In urban areas, the major street pattern is more distinct than in winter and autumn imagery. Intensively used commercial-industrial areas are visible (as a single class). Large construction sites are visible on the urban fringe. Large open spaces, major structures and buildings, new freeway segments, runways of large airports, aqueducts, major improved flood control channels and large stadia are all recognizable.

### 3.3.3 FALL

Subject image is a 9 inch by 9 inch false color print (band 4, 5 and 7) of ERTS 1 Scene 1468-17591 dated November 3, 1973 (Figure 3-15). Cloud cover obscures Metropolitan Los Angeles and much of the coastal mountain ranges. Desert areas, however, are generally clear and their details are sharply visible.

Vegetation in mountain areas is reddish brown. The brighter reds of summer and spring imagery have faded. Foothills and elevated desert areas are tan to light brown and more prominent than in 1972 autumn imagery. This is possibly due to above average vegetation growth in the previous spring and winter (1972-73). As a result irrigated fields, playas, old lake surfaces alluvial fans and towns are more clearly shown than previously. The street pattern in California City a desert subdivision, is easily visible.

## 3.4 DATA CONTENTS OF NON-STANDARD COLOR COMPOSITE TRANSPARENCIES

The initial NASA-NDPF plans were for a selection of standard bands for MSS imagery between (4, 5, 7) or (4, 5, 6). The early analyses indicated that the data contents of bands 6 and 7 when thus composited provided somewhat similar outputs/results. Hence, only the combination (4, 5, 7) in the standard filter sequence was retained and user-distributed.

The inauguration of the General Electric Photo Engineering Laboratory at Beltsville Md. almost at the beginning of reception of data from ERTS 1 provided the COLAGE team with a number of non-standard, almost unique products throughout the project. Non-standard, band-filter combinations, enlargements to non-standard scales and mosaics are the broad classes of such special products. A few of these analyses are presented here.

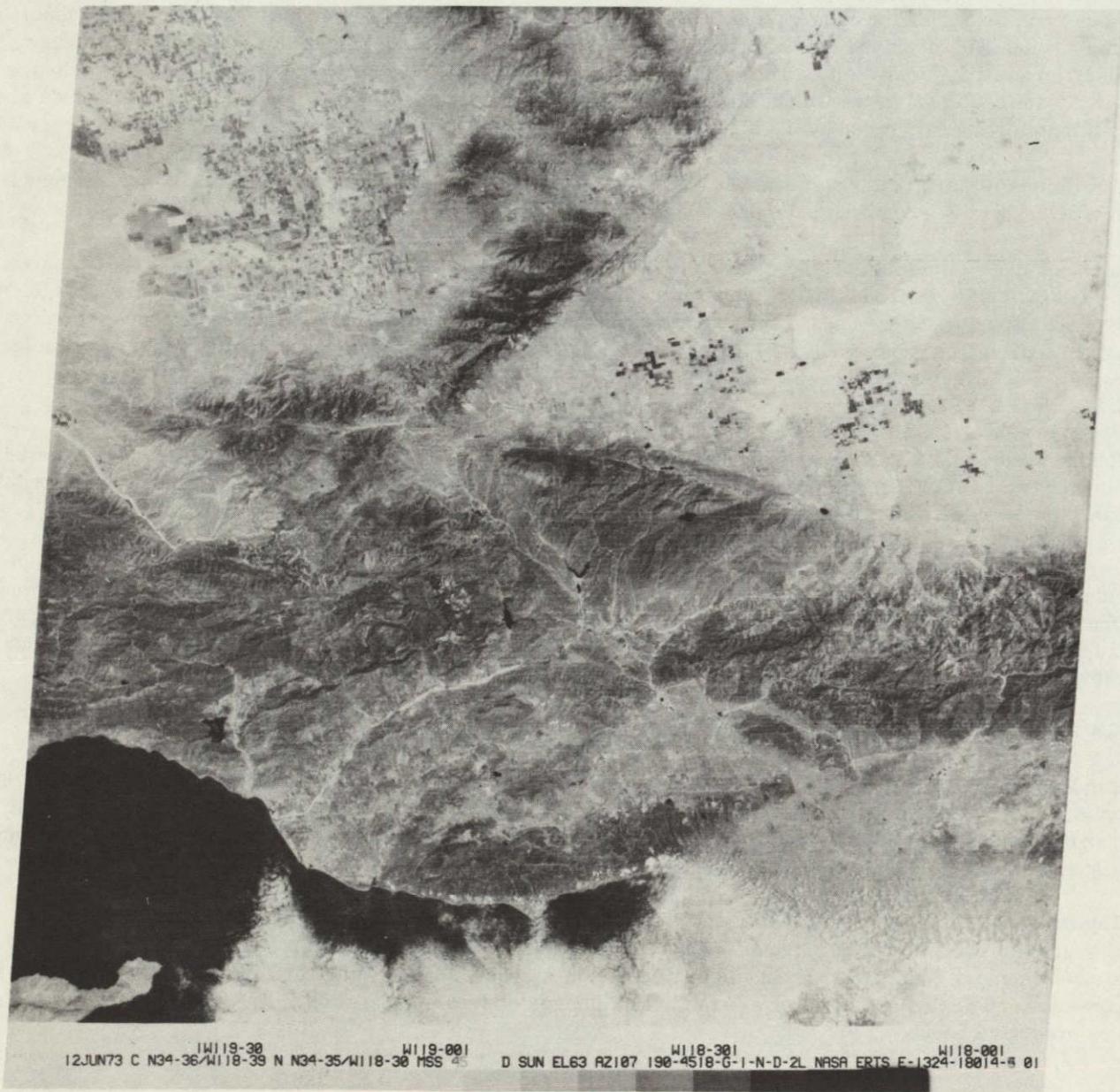
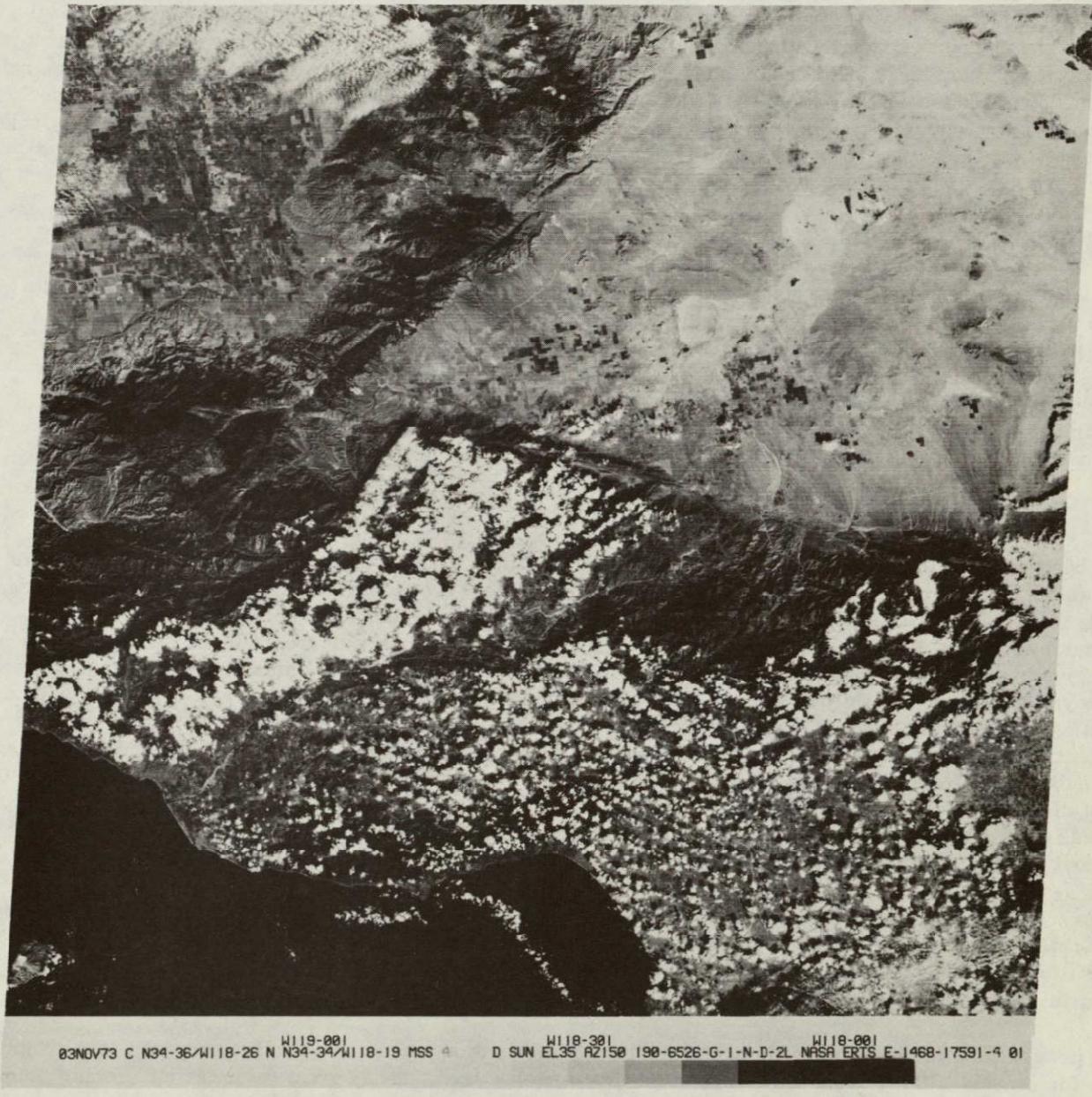


Figure 3-14. Scene 1324-18014, June 12, 1973



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03NOV73 C N34-36/W118-26 N N34-34/W118-19 MSS 4      W118-001  
D SUN EL35 AZ150 190-6526-G-I-N-D-2L NASA ERTS E-1468-17591-4 01

Figure 3-15. Scene 1468-17591, November 3, 1973

### 3.4.1 BANDS 5, 7, 4 (GREEN)

This band combination renders vegetation in various hues of green. (Figure 3-16). Irrigated crop lands are prominent and display a variety of bright greens. Higher mountains also show brighter greens. Gray greens are present in lower mountains and hills. Dull greens are visible along the elevated southwestern edge of Antelope Valley, an area of grassland and dry-farmed grain. Other elevated desert areas display blue-green hues. Unvegetated areas, such as playas and old lake beds, are gray to whitish gray. Recently burned areas are gray-black and very prominent. Water bodies are black and clearly outlined. In urban areas hundreds of formal open spaces are visible. These include (as a single class) such features as parks, golf courses, cemeteries and school playgrounds with vegetated surfaces. A great deal of variety is visible in the vegetation cover of the Los Angeles Metropolitan Area. Suburban areas have brighter greens. Inner city areas are gray to gray green. Very intensively developed areas with little or no vegetation are purplish brown. These intensively developed areas are used for commercial, industrial and very high density residential purposes. Beaches, sandy unimproved river channels, concrete lined flood controls channels and new freeways all show as light grays. Coastal wetlands are dark gray. Harbors, marinas and the runways of large airports can be seen. Many large buildings or clusters of buildings are visible as small white features. Large railway yards, oil refineries and clusters of high-rise buildings are dark brown or gray. Scores of major streets and highways are visible in urban areas. Terrain and drainage detail is sharply visible as are many major faults. Large new construction sites in urban fringe areas are light gray. Fire breaks (for fire protection) are visible in the Santa Monica Mountains.

### 3.4.2 BANDS 4, 6, 7 (YELLOW)

This band combination shows vegetation in various yellow hues. (Figure 3-17). It generally contains the same types of data as in the prior band combination. Irrigated farm fields and large urban open spaces show in brighter yellow. In areas such as the Oxnard Plain, citrus groves show as a tan or light brown hue in contrast with brighter yellow areas of field crops or vegetables. Only faint yellow tones show in higher mountain areas. Most mountain areas are dark gray or brown. Buildings and building clusters appear less sharp than in band combination 5, 7, 4 and high use intensity urban areas are less clearly shown.

### 3.4.3 BANDS 5, 4, 7 (REDDISH ORANGE)

This band combination shows vegetation in orange and red hues (Figure 3-18). It contains much the same data as the two prior band combinations. Certain types of field crops such as alfalfa show in bright orange. Other crops, such as citrus groves, are reddish brown. Heavily vegetated urban residential areas are brownish while formal open spaces are a pale orange. High mountain areas are reddish. They are less extensive in area than the high mountain vegetation areas shown in the green frame but more extensive than in the yellow frame. Between them, the three frames indicate much variety in naturally vegetated mountain areas. This band combination (bands 5, 4, 7) has less contrast in urban areas than either of the other two combinations. Street patterns are less clear especially in central cities; and high use intensity areas are not as distinctly framed as in the prior two combinations. Large buildings are less conspicuous. There is a hint of water discoloration in San Pedro Bay and four small artificial islands are visible off Long Beach. It would appear that band combination 5, 7, 4 contains the most vivid enhancement of vegetation and has the greatest clarity of overall detail.

In total, the various combinations contain a wealth of general information. For example, vegetation tones in mountain areas are portrayed differently in each reproduction. In agricultural areas there is a wealth of detail on plot size, shape and character. General soil character may be derived especially in desert areas, as well as much data about landforms.

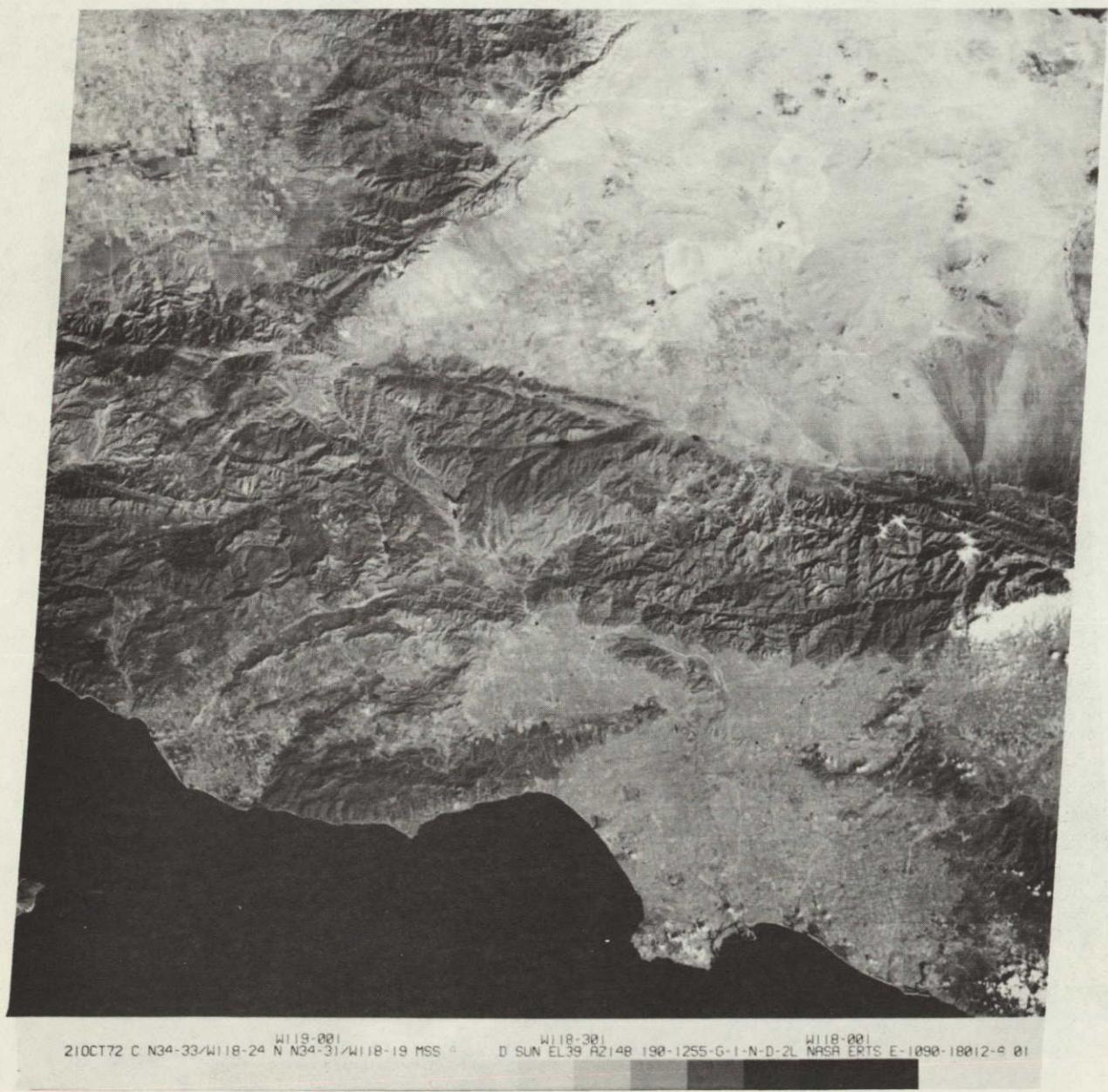
This imagery and its data content is useful for public information and communication purposes, for orientation, for conceptualizing about the nature of the Los Angeles area. It has great value for monitoring general conditions in the Los Angeles region and for directing more detailed, close up monitoring and data acquisition. The data content itself can be used for general urban and regional design work, land suitability studies, general resource inventories. The data could be used as inputs to very general policy and concept plans.

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21OCT72 C N34-33/W118-24 N N34-31/W118-19 MSS 5 W118-301  
D SUN EL39 AZ148 190-1255-G-1-N-D-2L NASA ERTS E-1090-18012-3 01

Figure 3-16. Scene 1090-18012, October 21, 1972



W118-001  
21OCT72 C N34-33/W118-24 N N34-31/W118-19 MSS  
W118-301  
D SUN EL39 AZ148 190-1255-G-1-N-D-2L NASA ERTS E-1090-18012-4 01

Figure 3-17. Scene 1090-18012, October 21, 1972 (Bands 4, 6, 7)

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Figure 3-18. Scene 1090-18012, October 21, 1972 (Bands 5, 4, 7)

### 3.5 UTILIZATION OF ENLARGED ERTS IMAGES

Enlargements of ERTS scenes from both black and white and false color negatives have been made at a number of facilities. For the COLAGE team, two sources of rather unique enlargements were available: (a) the GE Photolab and (b) the Hughes Aircraft Photolab. While the former started with the standard NASA negatives (70 mm), the latter generated non-standard master negatives (5.5 inch) directly from the high density video tapes. Only the band 7 images for only one date were available in this form. The discussion below is grouped according to these image sources and scales. It should be pointed out that unlike most other products that were solicited and available in pairs, at Los Angeles and Valley Forge, these enlargements were available only to COLAGE-RPC.

#### 3.5.1 1:250,000 SCALE, FALSE COLOR PRINT

The subject of these comments is a 1:250,000 enlargement of ERTS-1 Scene 1144-18015 (see Figure 3-3), dated December 14, 1972, covering Metropolitan Los Angeles and environs. The enlargement is a false color print (bands 4, 5 and 7). The scene is clear except for fog in the San Joaquin Valley (northeast corner).

Snow cover is prominent in higher mountain areas and in limited areas of the floor of Antelope Valley. Terrain detail in the mountains is generally very clear except for high, steep north facing slopes which are obscured by shadows. Likewise, drainage patterns are visible except in areas obscured by shadow.

In desert areas major land form features such as alluvial fans and playas are easily discernible. A varied pattern of soil coloration is also visible.

Water features are clearly identifiable down to a size estimated at approximately 10 acres. Shapes of larger water bodies are generally definable.

Major fault patterns stand out clearly. A linear feature, suggesting the possibility of a new fault, is visible along the north side of the Santa Monica Mountains.

A variety of vegetation patterns is discernible. Irrigated crop districts are clearly visible in the western Mojave Desert (Antelope Valley) although winter dormancy has imparted subdued color hues. Dry farmed fields are visible in the western Antelope Valley.

Other farming districts are visible in southern Ventura Country, Orange County and in the San Bernardino Valley. In these areas, citrus crops are distinguishable by their dark reddish hues. Dairying districts (Corona and Cerritos) stand out by reason of their dark tone and small size.

New (spring) grass growth is visible in the Moorpark, Newhall, Agua Dulce, Chino and west Antelope Valley areas. The general vegetation pattern of hill and mountain areas is generally visible. Tones are somewhat subdued apparently due in part to winter dormancy.

Urban vegetation patterns are varied. Parks and golf courses (open spaces) show as pale pinks. Estate and higher income residential areas manifest reddish-brown hues. These include Rolling Hills, Palos Verdes Estates, La Habra Heights, North Beverly Hills, Brentwood, Bel Air, Flintridge, San Marino, Hancock Park and Arcadia. The relatively heavier vegetation patterns of the west San Fernando Valley, Westchester, North Pasadena - Altadena and Covina are distinguishable. Inner city areas (Long Beach and Central Los Angeles) manifest reddish-gray tones. Gray tones in major industrial and commercial areas stem, in part, from the relative absence of vegetation. Desert areas with sparse vegetation have gray or tan hues.

Sand beaches are visible along the coastline as whitish linear features.

Urban areas can be generally delineated. Major street and highway patterns are visible. However, streets of urban areas are less visible than in summer imagery. This may be due in part to lowered contrast stemming from winter dormancy of urban vegetation. Only new portions (those under construction or recently completed) of the freeway network can be seen.

Improved flood channels (concrete surface) are visually prominent. Branch channels of dry braided streams are also easily discernible. Major stream channels with water can be identified.

High use intensity of urban areas are visible. Major rail yards stand out by their dark tones. Larger harbors, marinas and airports are discernible. High-rise districts also manifest very dark tones, due in part to shadow. Dozens of large structures (industrial structures and large commercial buildings) can be distinguished.

Large new construction sites in urban fringe areas are prominent by reason of their light tones and irregular shapes. Major quarry sites are also distinguishable from their location and visible pits, many of which are water filled.

Some new developments on the urban fringe are visible because of their light tones.

The great strength of the scene is not as much in these varied details as in the ability it gives to interrelate all of this detail and manifest the entirety of urban Los Angeles and its environs.

The scene yields a great amount of data which would be useful for general planning operations. It can be used to identify areas where more detailed data sources are needed. The scene is also useful for general orientation and for monitoring purposes. It can contribute to the preparation of land cover, land use intensity and land suitability analyses. It is also valuable as a base for displaying other types of data.

### 3.5.2 1:103,000 SCALE, FALSE COLOR PRINT

The enlargement used for this evaluation is a false color composite (bands 5, 6, 7) from ERTS Scene 1144-18015, dated December 14, 1972 (see Figure 3-3). The enlargement, part of the above ERTS scene, covers the site of Metropolitan Los Angeles in Orange and Los Angeles Counties. It has a scale of approximately 1:103,000.

This enlargement contains a wealth of data. It provides an overview of virtually all of the Los Angeles Metropolis together with features surrounding the site. Terrain and drainage features are shown with a clarity of detail unattainable through the use of topographic maps of a similar scale; texture, tone, color and pattern permit the general delineation of boundaries between urban and non-urban areas.

The pattern of urban vegetation tells much about the character of the urban area. The most luxuriantly vegetated areas stand out and suggest above average environmental quality. Central city areas have less than average vegetation which suggests a lower degree of environmental quality. Dozens of major open spaces are visible and shapes are defined with enough clarity to permit accurate location. Internal details can be distinguished in many open spaces suggesting the location of structures and paved areas.

Also visible are hundreds of smaller open-spaces (down to about 5 acres in size); examples are school playgrounds and community parks. The composite pattern of these, visible for the first time in ERTS imagery, provides a means of distinguishing central cities from suburban areas and suggests difference in urban design and public facility policy among the many jurisdictions in the metropolis.

Most of the major street pattern is visible. The dominance of a rectangular grid is clearly evident. Other visible linear features include flood control channels, stretches of newly constructed freeways and the principal railway corridors.

Dark tones define major water bodies. Harbors, marinas and major airports are visible. Major intensely used urban areas (commercial and industrial) can be distinguished. Sand beaches and the shape of major construction sites can be seen.

The principal railyards and some very large industrial facilities are distinguishable as to location and shapes. Scores of major buildings and structures (mostly industrial) can be seen. A major agricultural district (devoted to dairying) is visible.

The value of this scene lies in the wholeness and clarity of this broad overview. Thousands of details are interrelated to give a powerful grasp of character and spatial organization of the massive 1,500 square mile urban area.

This enlargement is useful for inventoring the general spatial organization of the metropolis. It would permit the formulation of general, metropolis - wide "first cut" design policy. It would also allow a "first cut" definition of metropolitan wide environmental quality. It is useful, as well, for general monitoring of human and environmental events and processes. This ability to monitor provides the basis for timely public action aimed at managing significant events and process (both short and long term) affecting the character of the urban area.

### 3.5.3 1:200,000 SCALE, BLACK AND WHITE PRINT

The subject of these comments is in a black and white (band 7) print of an ERTS image of the Los Angeles area dated August 10, 1972. The image is an enlargement with a scale of 1:300,000 provided by Hughes Aircraft Company.

This enlargement contains a wealth of detail. Several hundred street, highway and freeway alignments are visible. Of all the ERTS film products obtained over Los Angeles, this contains the clearest and most detailed urban street pattern. Nearly all of the major streets and highways in the metropolitan area are visible.

Likewise, a very detailed urban open space pattern is visible. Again several hundred open space features (parks, golf courses, school playgrounds - visible as a single class) can be located down to a minimum size of approximately 3 acres. The shapes of major parcels (estimated at 50 acres and above) of open land can be generally defined. Scores of water bodies are also visible down to the same threshold as in Open Space approximately 3 acres). The shapes of water bodies are more clearly definable than is true in the case of open space.

Several dozen large buildings and structures are visible. In a few instances their shapes are generally discernible.

In the Santa Monica Mountains the more urbanized eastern sector is distinguishable from the less urbanized western sector by contrasts in texture and tone.

The enlargements contain a great amount of topographic and drainage pattern detail. Sand beaches are visible along the coast. In the desert regions, there is a great deal of tonal variety useful for generalized soils mapping.

Irrigated agricultural areas are highly visible. Land subject to recent strip cropping can be distinguished. Accurate shape definition is possible for most fields. Many fallow or abandoned farm fields are also visible in the Ventura County area. Windbreaks are visible in districts devoted to citrus culture.

Much geological and landform data is also obtainable from the enlargement. A number of large fault lines can be seen.

In urban and regional planning, the image is useful for a number of purposes. These include general land suitability analysis, general resource surveys, environmental quality assessment, very generalized land use surveys, urban design studies, monitoring of major environmental events and process, and orientation. This information in turn, would permit formulation of very general "concept" type plan.

### 3.5.4 1:80,000 SCALE, BLACK AND WHITE PRINT

The enlargement used as the basis for these comments has a scale of 1:80,000. It is from NASA ERTS Image E-1018-18010, dated August 10, 1972. The enlargement is a black and white print (band 7) provided by Hughes Aircraft Company and covers the urbanized area of Metropolitan Los Angeles South of the San Gabriel Mountains from Thousand Oaks to Newport Beach.

This enlargement contains data similar to the 1:200,000, band 7 enlargement discussed in Section 3.5.3. The general alignment of the major street grid of Metropolitan Los Angeles (several hundred street segments) is visible. The freeway system is generally less visible than the major streets. Also visible are the general locations of many hundreds of open spaces. The shapes of larger open spaces are generally discernible; and in some cases the presence of facilities within them is discernible.

Water bodies down to a size of 3 or 4 acres are visible and, as in the case of larger open spaces, their shapes are definable.

The runways of major airports are discernible. Also visible are several dozen major structures and buildings, mostly industrial and commercial can be seen. Tonal variations permit the general definition of high intensity land use areas.

In mountainous areas, much topographic and drainage detail is visible. Fire breaks can be seen in some mountainous districts.

The enlargement is useful for general design analysis and for general land suitability analysis. It is also very useful for orientation relative to the general character and spatial organization of the Los Angeles region.

### 3.6 MOSAICS OF ERTS SCENES

Two California mosaics were used at one point in the Los Angeles analysis. These color composite mosaics were produced by the GE Photographic Engineering Laboratory from several adjacent standard ERTS images. When processed with matching contrast and color balance, mosaics can reveal a geological fault, show an entire river system or display a whole range of mountains. Figure 3-19 is the mosaic of the whole State of California, and Figure 3-20 shows the Southern California region. Comments on the value of these mosaics in the Los Angeles study for regional and urban planning are presented in the following paragraphs.

#### 3.6.1 STATE OF CALIFORNIA MOSAIC

The mosaic used for this evaluation (Figure 3-20) is a false color (bands 4, 5 and 7) print approximately 6 by 9 inches of the State of California and environs. It was made from 42 multispectral images (bands 4, 5 and 7) returned from ERTS. The following comments are made from the perspective of a metropolitan planner interested in the usefulness of data contained in the mosaic for metropolitan policy making and execution. The perspective is from Los Angeles.

One-piece mosaics (air photo mosaics) of the entire state have not been commonly available prior to ERTS in black and white and especially not in color. This mosaic, therefore, furnishes a powerful new overview with a surprising amount of detail. For example, the CBD (Central Business District) of Los Angeles is visible and can be seen in relation to an area of perhaps 200,000 square miles. The proximity of Los Angeles to desert areas, in comparison with the San Francisco Bay communities, is much easier to grasp on this mosaic.

Aside from the visible detail, the immediate obvious value of the mosaic is its usefulness for orientation.

1. Size and shape of the urban area of Los Angeles may be compared with the shapes and sizes of a whole range of other major features, such as, other major urban areas, major landform features and agricultural areas.
2. Coloration of the Metropolitan Los Angeles area may be compared with the gross coloration (very detailed color comparisons may not be reliable) of other areas in the mosaic.

#### 3.6.2 LOS ANGELES REGIONAL (SOUTHERN CALIFORNIA) TEST SITE MOSAIC

This mosaic is a positive false color transparency made from bands 4, 5 and 7, measuring 14 by 14 inches. (See Figure 3-20, reduced and in black and white print, only.) It covers the area from Santa Barbara on the

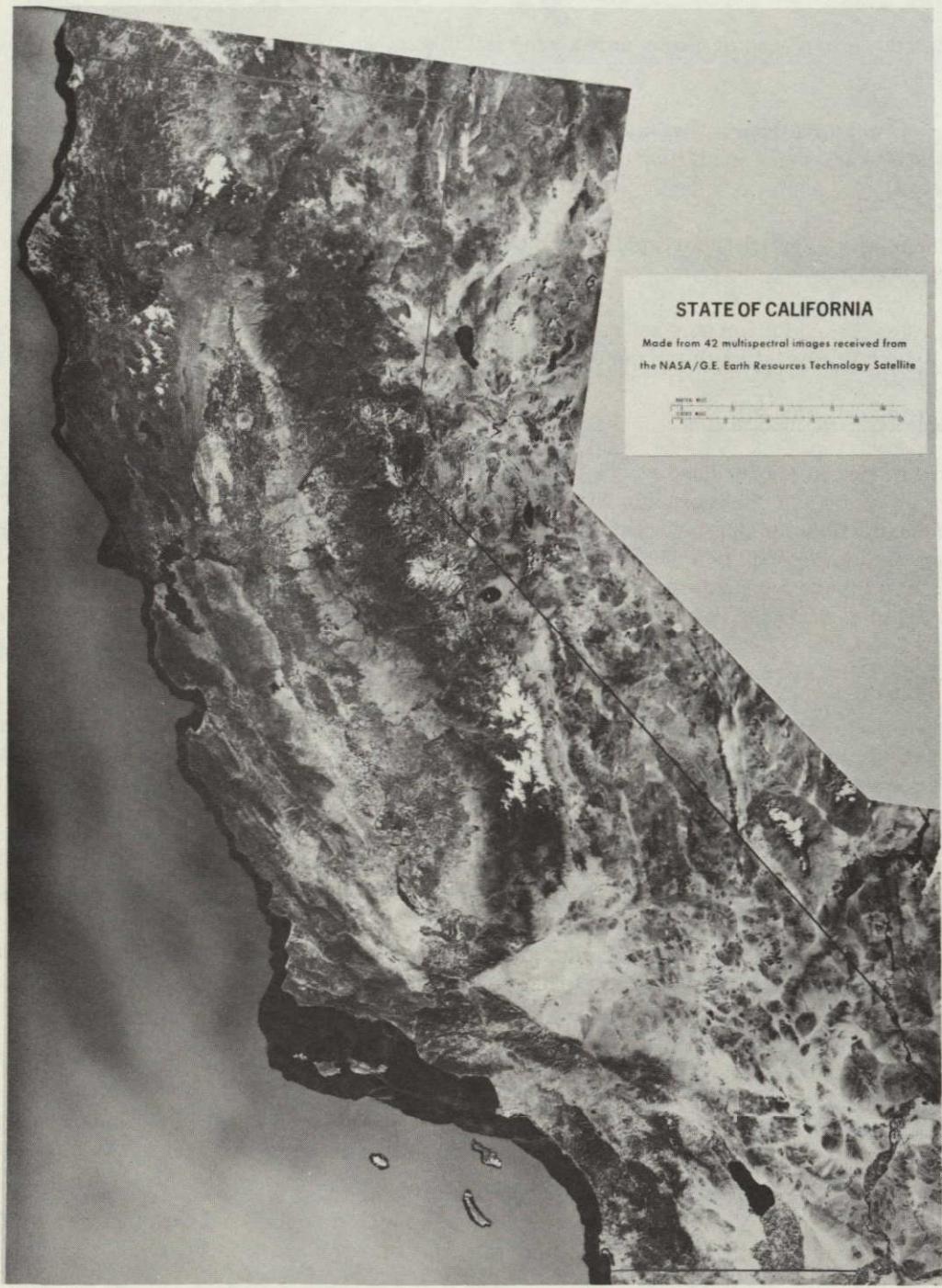


Figure 3-19. Mosaic of the State of California

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Figure 3-20. Mosaic of Southern California/Los Angeles Regional Test Site

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west to the eastern edge of the Salton Sea; and from Tijuana, Mexico on the south to the south edge of Owens Valley on the north. The mosaic is undated but from the amount of red present in the scene, it would appear that the ERTS frames were obtained in the late spring or early summer.

This mosaic, like the other mosaics, provides a powerful overview of the setting and site of Los Angeles valuable for orientation; and for analysis of the relation between the metropolis and the surrounding region. Regional landform provinces are easily visible, as are major types of terrain. Landscape coloration and visible structural features yield considerable detail of geographical and soil conservation. Landscape color is also a key to the general nature of vegetation. Considerable drainage detail is visible.

Major agricultural districts are clearly visible. Their details and patterns suggest much about the relative character and condition of these areas. Field patterns within many agricultural areas are discernible.

Major urban areas are visible and can be generally compared and contrasted in terms of size, setting, and major site details. A range of generalizations can be made about their nature.

Major urban and agricultural areas can be compared. These in turn can be related to non-urban, non-agricultural mountain and desert regions. Various degrees of vegetative cover are discernible.

General degrees of landscape coloration are visible. This is an important indicator of environmental condition and environmental quality and a useful input to formulating plans and development policies.

Of course, the mosaic contains data in general terrain, landforms, geology and drainage. This is useful data for determining land suitability which in turn is of value for land use planning.

Local planners would generally find this type of data useful for orientation, illustration and public information. Regional agencies would find the data useful for very general types of planning operations including orientation, illustration, public information, land suitability, analysis, environmental surveys, environmental quality analysis, very general land use surveys and generalized land allocation useful for preparing "concept" type plans.

Urban landscape coloration permits some general conclusions to be drawn about urban environmental quality. Much detail is visible such as major water bodies, large open spaces, major grading sites, and brush fire scars.

Landscape coloration suggests that Antelope Valley (the Western Mojave Desert), the San Bernardino Valley Perris Upland, and the Carrizo Plain together with the unirrigation fringes of the southern San Joaquin Valley have similar arid environmental conditions.

In addition to its value for orientation, the mosaic would permit conclusions to be drawn about general environmental conditions and the general nature of land cover. This in turn could permit general land suitability conditions to be determined which would allow very general land use allocations to be made. Mosaics such as this could also be used to monitor a broad range of environmental processes and conditions such as distribution and vigor of vegetation; seasonal changes in agricultural regions; and the results of human actions and environmental events and processes.

Systematic accumulation of mosaics over a long period of time would allow the construction of a historical record of the occurrence and distribution and major environmental events and processes over a wide area. This would be useful for trend determination (change detection) which is valuable for forecasting -- a key planning problem.

The above capabilities would permit urban planners to tackle a much neglected problem -- the management of the relationships of cities to their interlands. Heretofore, urban planners have concentrated almost exclusively on the internal problems of cities.

### 3.7 ERTS IMAGERY FOR COMPARATIVE URBAN STUDIES: LOS ANGELES VS OTHER METROPOLITAN AREAS

Imagery of a number of urban areas -- New York/Philadelphia, Washington/Baltimore, Boston, San Francisco, Chicago, Athens, Tokyo/Osaka, and New Orleans (Figures 3-21 through 3-28) -- were used in this assessment. The imagery available was less than ideal. It involved a melange of dates encompassing all seasons, a variety of scales -- mostly 1:1,000,000 or 1:500,000; and a variety of color composites and black and white bands. In spite of these limitations and lack of control, some useful observations can be made.

The imagery allows a comparison of the sites and settings of the metropolitan areas. The site of Los Angeles appears more constrained by natural barriers (shorelines, mountains, and hills) than is generally true of most of the other areas. (Osaka-Kyoto is a possible exception.) The uniqueness of the setting of Los Angeles is apparent: Los Angeles lies between the sea and an arid to semi-arid mountain and desert environment. Los Angeles lacks a major natural harbor. Its metropolitan area contains extensive rugged, hilly areas. There are relatively few streams and lakes.

The urbanized area of Los Angeles appears to be much more extensive than those of other metropolitan areas. The central cities of other metropolises appear much darker in tone (band 7 or bands 4, 5 and 7) and comparatively more extensive than in the case of Los Angeles. These observations, in combination, suggest that Los Angeles is less intensely developed than the other major urban areas.

Los Angeles is the only one of the major cities where a grid street pattern with hundreds of street segments are visible. In other cities only, the broad radial pattern of the principal transport corridors can be seen (this is visible in Los Angeles too).

Likewise the pattern of open spaces is much more visible in Los Angeles than the other cities. The edges of the Los Angeles urban area appear more sharply defined while the edges of its high intensity urban areas appear less sharply defined than in the other metropolitan areas. More large structures and buildings are visible in Los Angeles and the central business area of Los Angeles is better defined.

Water discolorations were visible near many of the urban sites including Los Angeles. More large fault lines are visible in the area around Los Angeles than any other cities identified. Also, more wild fire scars were visible near Los Angeles.

In general, the extent and internal spatial organization of Los Angeles stands out with more clarity than is true of the other metropolitan areas observed.

### 3.8 SUMMARY REMARKS ON THE MANUAL PHOTointerpretation STUDIES

The above discussions serve to identify some of the potential for urban and regional studies of ERTS imagery. A more careful selection of imagery (and the accumulation of imagery over urban areas on a continuing basis (in order to give a long trend) would yield highly useful data for urban and regional planning.

This data would permit general comparative monitoring of certain development trends and studies in comparative environmental quality and comparative metropolitan design. These capabilities are relevant to urban policy making. Heretofore, urban planners have been concentrating heavily on the internal characteristics and problems of their urban areas. ERTS facilitates the entry of planners into two other major areas vital to policy making: comparative studies of urban areas; and studies external to urban areas (using mosaics) centering on the relation of cities to their hinterlands.

While considerable amount of detailed spatial and temporal information was being extracted by the County Co-Investigators throughout the project duration by photointerpretation of the rather large number and variety of ERTS film products - with specific corroboration from the equally vast and continuing amount of aircraft underflights imagery as well as ground observations - the primary outputs of this activity necessarily were qualitative. Thus, even though a number of the overlays - especially in the urban areas - might appear to

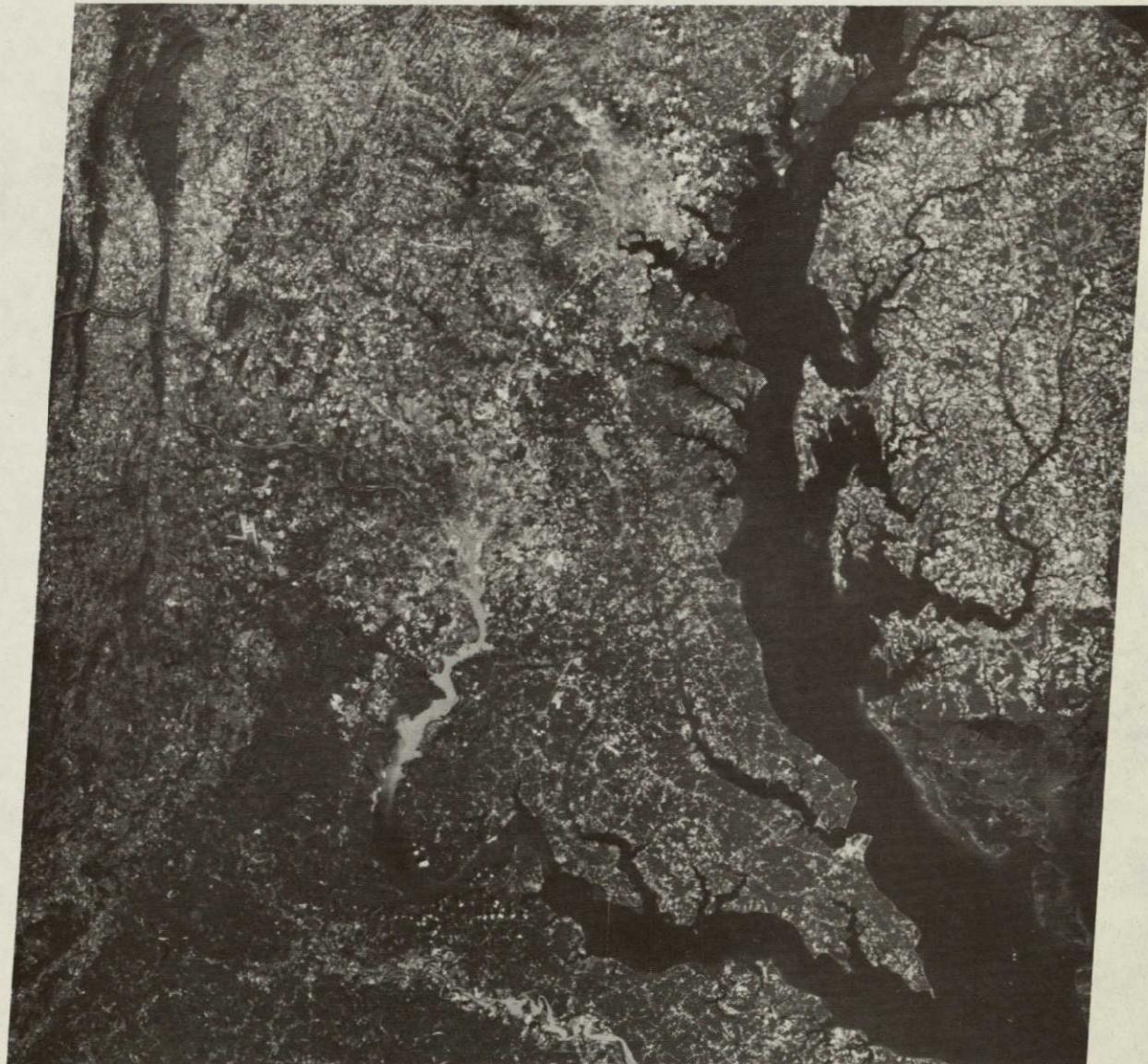
tantamount to land use 'category' delineations, they were not "categorical" enough in the judgments of the COLAGE team members to warrant a manual development of "Land Use Map" for the County from the ERTS scenes per se.

However, the photointerpretation effort indeed served to provide the general background as well as specific spatial and temporal insights into the problems that were - often in parallel - tackled in the machine analyses. studies discussed in Sections 4 and 5.



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180C172 C N40-18/W074-51 N N40-17/W074-48 MSS D-SUN EL38 AZ150 191-1100-N-1-N-D-2L NASA ERTS E-1079-15(3)-8

Figure 3-21. ERTS Image of New York/Philadelphia, October 10, 1972.



11OCT72 C N38-54/W076-48 N N38-52/W076-43 MSS D SUN EL38 RZ149 (9)-1114-N-1-N-D-ZL NRSA ERTS E-1000-15(92-1-0)

Figure 3-22. ERTS Image of Washington, D.C., October 11, 1972

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28JUL72 C N41-54/W071-32 N N41-51/W071-26 MSS 4 D SUN EL57 AZ125 191-2068-N-1-N-D-2L NASA ERTS E-1005-15005-4 02

Figure 3-23. ERTS Image of Boston, July 28, 1972



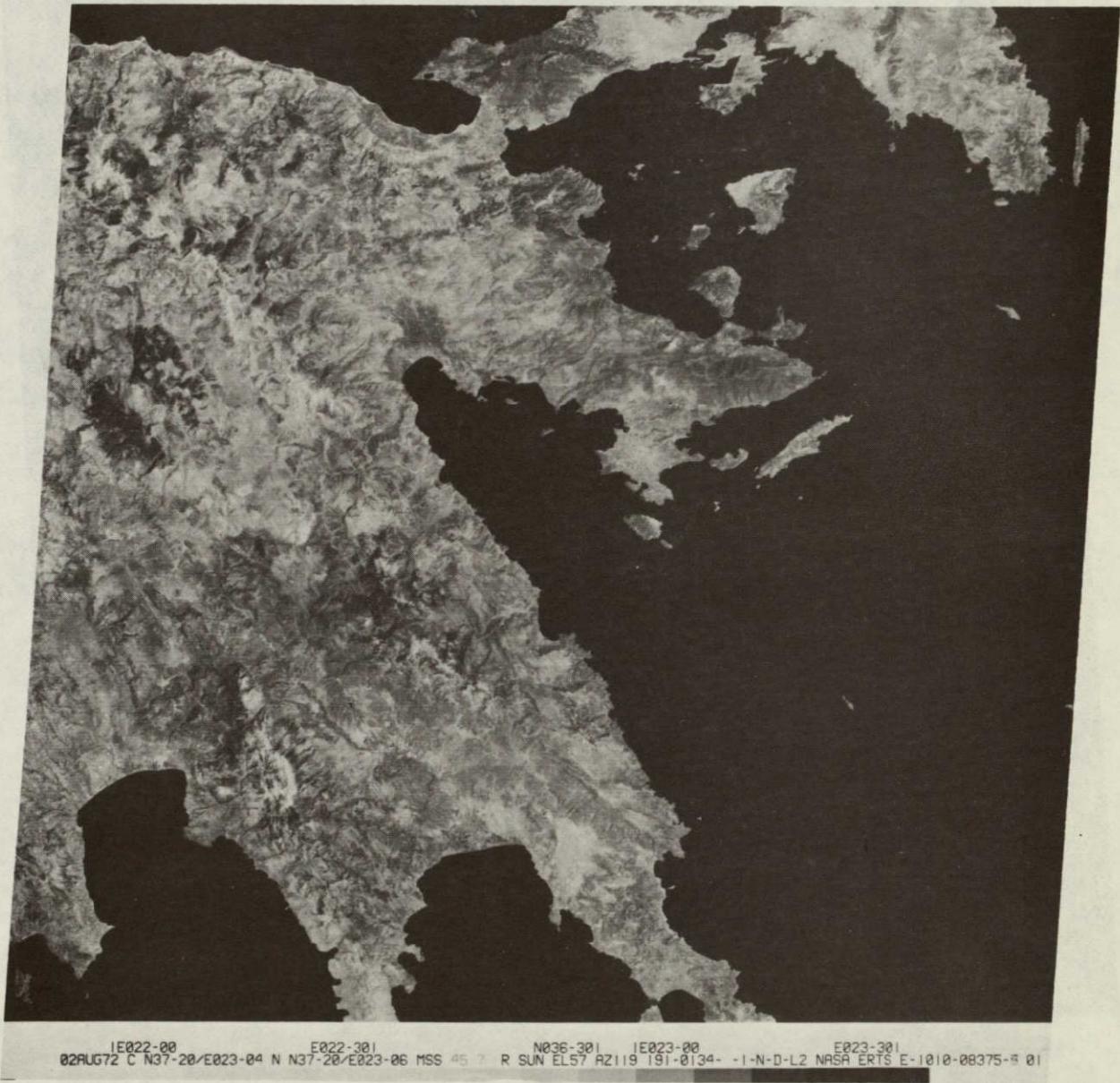
Figure 3-24. ERTS Image of San Francisco, November 29, 1972

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Figure 3-25. ERTS Image of Chicago, October 2, 1972



IE022-00 E022-301 N036-301 IE023-00 E023-301  
02AUG72 C N37-20/E023-04 N N37-20/E023-06 MSS 45 7 R SUN EL57 AZ119 191-0134- -1-N-D-L2 NASA ERTS E-1010-08375-5 01

Figure 3-26. ERTS Image of Athens, August 2, 1972



E139-381  
26NOV72 C N35-53/E140-09 N N35-51/E140-12 MSS 4

E140-201 N035-001 E140-301  
R SUN EL28 AZ153 190-1747-A-1-N-D-ZL NASA ERTS E-1126-00484-4 21

Figure 3-27. ERTS Image of Tokyo, November 26, 1972



07AUG72 C N30-35/W089-26 N N30-34/W089-24 MSS 45 7 D SUN EL58 AZ110 190-2208 - I-N-D-2L NASA ERTS E-1015-16013-A 01

Figure 3-28. ERTS Image of New Orleans, August 7, 1972

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SECTION 4  
ELECTRONIC ANALYSIS OF ERTS PRODUCTS,  
PROCEDURES AND CASE HISTORIES

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## SECTION 4

### ELECTRONIC ANALYSIS OF ERTS PRODUCTS - PROCEDURES AND CASE STUDIES

#### 4.1 CHARACTERISTICS OF MACHINE-AIDED ANALYSES

The nine elements defined in Section 3 used by a photointerpreter to analyze imagery are a complex set of conditions which he mentally integrates to obtain results. These findings are powerful qualitatively, but classical photointerpretation itself lends to rather limited quantitative value. Results are passive because they cannot be further manipulated, and the information is only as reliable as the skill of the interpreter. This is especially so for ERTS data.

When a machine is introduced to aid in processing data the task of extracting information is made more quantifiable. Image analysis by machine can be done either optically or electronically, but in either case the mechanism proceeds in a simplistic, "brute force" fashion and grinds out a vast amount of data which can be used as inputs for human analysis. An additional advantage of machine-aided electronic analysis is that the output can be made compatible with computer inputs. ERTS users can further use the data in specialized computer applications.

#### 4.2 FUNCTIONAL FLOW OF MACHINE ANALYSIS

The flow of data that was analyzed electronically for the Los Angeles Study, is functionally shown in Figure 4-1. Source and reference data were the principal inputs; the analysis addressed to the four categories of: Data Characteristics, System Features, Technique Development, and Application Studies. The output was a set of evincive data that could be used by the Los Angeles County Planners.

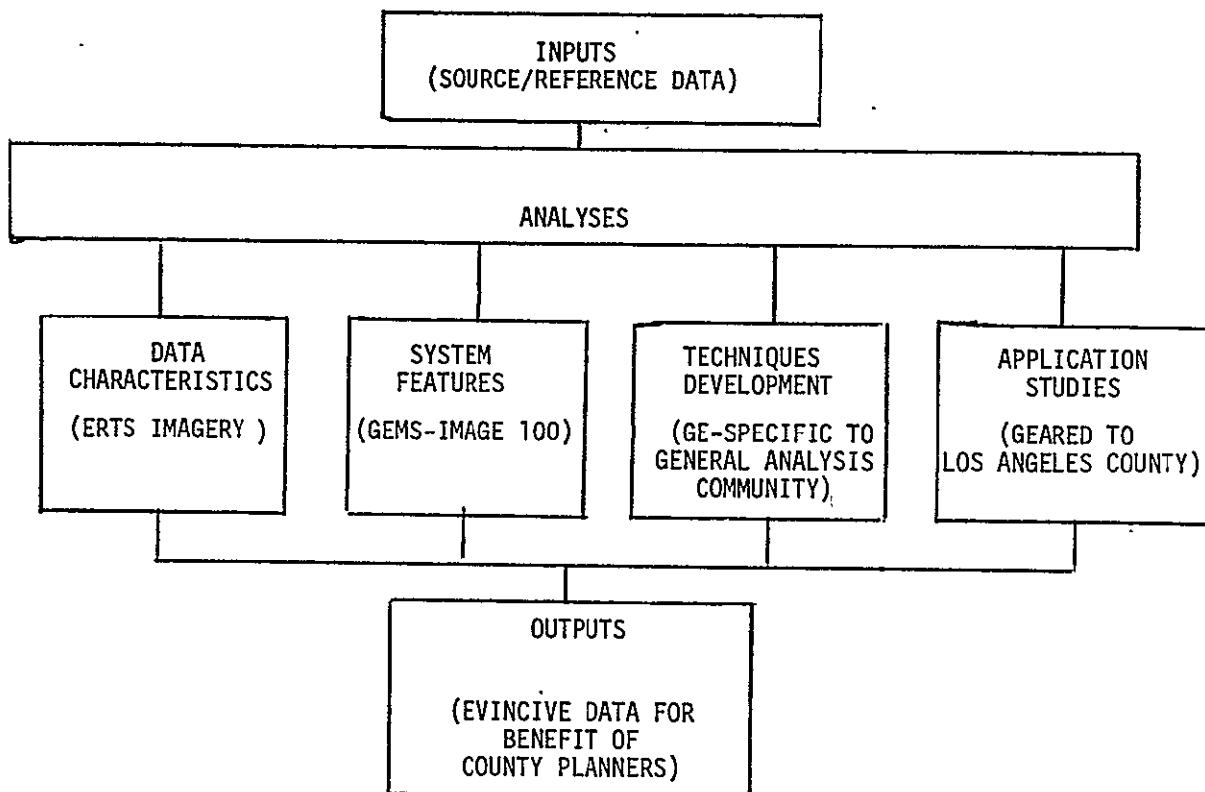


Figure 4-1. Electronic Data Analysis Flow

Characteristics of source data, namely of the ERTS images, and aircraft underflights - and of reference data in the form of maps and charts needed to be well understood. The system features of the General Electric Multispectral System (GEMS) and IMAGE 100 used in the machine analysis phase of the study. (Refer to Appendix B) had to be appreciated and utilized to enable development of techniques which aided investigators to carry out a set of applications studies which put results at the disposal of the Los Angeles County Planners that were rather innovative in nature.

Data came principally from the Multispectral Scanner (MSS) on board ERTS-1, and the U2 underflights. The MSS on ERTS-1 furnished the inputs in four bands that covered the spectral range from 0.15 to 1.1 micrometers. The U2 data was from a number of multi-band camera configurations, using a variety of film types, sizes, etc., and from a scanner that covered the range from 0.38 to 1.09 micrometers in 24 bands. Images from ERTS and U2 were multi-temporal which enabled the investigators to contrast the area at different seasons of the year.

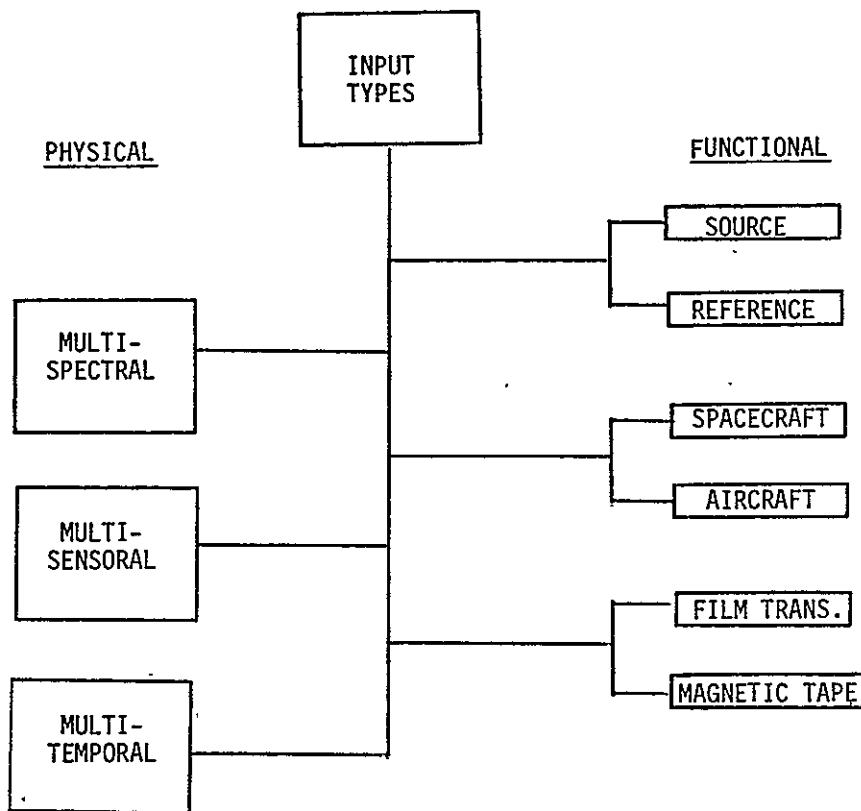


Figure 4-2. Types of Possible Inputs for Electronic Analyses

#### 4.3 PHASED USAGE OF GEMS AND IMAGE 100 SYSTEMS

GEMS was used for machine analysis of this study from September 1972 through June of 1973. From October 1973 the IMAGE 100 equipment at Daytona Beach, and more recently at Beltsville, Maryland, was available.

Color composite images were the only inputs that could be used on GEMS but the IMAGE 100 accepted both transparencies and computer tapes, so tape inputs were used in the latter part of the Los Angeles investigation. Through the use of the scanner input on IMAGE 100, images supplied from U2 and C130 aircraft were also machine-analysed. All of the team members, including the Los Angeles Planning Commission representatives, had "hands on" time on both types of equipment.

#### 4.4 CASE STUDIES: GENERAL COMMENTS

The following discussion of test cases considers data content, techniques, and evaluation of results in a research and development mode in keeping with the ERTS mission goals. Studies were based on the interest of the individual investigators as well as through interactive studies based on the interest of more than one member of the Los Angeles study team. Table 4-1 gives a topical list of the various machine-aided analysis studies discussed in more detail in the subsequent subsections.

Table 4-1. Topical List of Case Studies

Section	Study Topic	Region/Discipline of Interest	Analysis/Method/Techniques Development
4. 5	Area Measurement of Surface Water Bodies	Water Resources	Training and Testing: Classification, Signature Extension
4. 6	An Agricultural Pattern Analysis in Antelope Valley	Agriculture	Training and Testing: Photo-interpretation Mode
4. 7. 2	Early Unsupervised Learning Runs-Single Band Level Slicing	Urban Core	Slicing and Clustering: Pre-Processing
4. 7. 3	Seven-Theme Synthesis	Urban Core	Hybrid (Combination of Training and Testing and Slicing and Clustering)
4. 7. 4	Multi-band Slicing/Clustering Analysis	Suburban	Slicing and Clustering: Sequential Analysis
4. 9	Analyses of Residential Areas	Residential	Training and Testing: Test Sites Structures
4. 10. 2	Grading Sites	Construction	Training and Testing: Change Detection
4. 10. 3	Sheep Creek Fan	Geology	Training and Testing: Fine Structure Analysis
4. 10. 4	Bouquet Reservoir	Hydrology	Training and Testing: ERTS/U2 Registration
4. 10. 5	Wilshire Country Club	Recreation	Training and Testing: Multi-cycle Analyses
4. 10. 6	Marina del Rey Area	Coastal Area	Training and Testing: Temporal Compositing

#### 4.5 AREAL MEASUREMENT OF SURFACE WATER BODIES: SIGNATURE DEFINITIONS

This substudy was an excellent example of training using the a priori approach. Visually a resolution of a very small number of ERTS cells (an area equal to 1-1/4 acres) was detected: reservoirs within parks such as Hollywood Park and MacArthur Park were identified. A large number of water bodies were selected for area measurement within the county using both GEMS and IMAGE 100.

Ground truth for this substudy was supplied by the California Board of Water Resources and the Water and Power Department of the City of Los Angeles. The classes of water bodies in the area are almost limitless for potential analyses. To restrict the number of candidate water "themes" to a manageable number, water quality data was needed. Unless such experiments are planned and ground truth of the area obtained in advance, investigations yield only quasi-quantitatively significant results. Almost the whole range of concepts basic to remote sensing emerged in their sharpest form in the course of this study. Summarizing these at this point will also set the stage for obtaining insights into the subsequent substudies.

To begin with, some definitions and examples: a class of objects is what a user defines to be of interest specific to his application. Thus, the class of water bodies of interest to planners would be characterized by their spatial distribution (vis-a-vis other land use classes such as open space, recreation, resource supply) and surface areas. To water resource managers, on the other hand, water volume, quality and their spatial temporal variations would be minimally desired in their water classes.

A theme is extracted by an analyst from available remotely sensed data. It is thus a function of the data characteristics as well as of the information extraction tools and techniques. Manual photointerpretation of ERTS data in film format, both in individual bands and color-composited, yields much qualitative and quasi-quantitative thematic information for surface water bodies. Beyond such spatial identification and seasonal observation, here it was felt that the quantitative machine-aided thematic measurements of surface areas from ERTS film and tape data were minimally desired for regional planning use.

A signature is the specific criterion used to isolate a theme while a qualitative "signature" using the elements of photointerpretation in Section 3.1 could be developed for water themes isolation, again the explicit spectral signatures derived from "training samples" in GEMS and IMAGE 100 analyses yielded the results of interest in this study. (Figures 4-3 A, B, C)\*

Ground Truth is the collection of data by a user pertaining to a class supplied to an analyst for signature delineation to synthesize the corresponding theme as well as for evaluation of the final results. In a fully interactive process these activities are inerated in a closed loop fashion. (See Figure 4-4) in the case at hand, of water bodies area measurement, while the machine analysis did suffice the primary user's needs, the secondary user's requirements as well as evaluation of the results to meet them were addressed in a limited fashion within the scope and resources constraints of the study.

The sequential analyses have been reported in respective stages earlier (See Figure 4-4E). Table 4-2 shows one set of data and results: the in-situ numbers being supplied by the secondary users, the aircraft data being measured planimetrically from 1:130,000 scale imagery. Attempts to corroborate it by electronic measurements were inconclusive in view of the rather high density of the film for scanner digitization. The GEMS results were obtained from a Band 4, 5, 6 color transparency while the IMAGE 100 measurements were integrated from sub-themes obtained by using all the four-channel data with simple mono-cell training and classification. More complex signature structure and theme synthesis was attempted in a preliminary fashion only. Utility of such detailed analyses is more difficult to ascertain without a more rigorous program for ground truth acquisition as well as more explicit considerations of border pixels and signature extension.

Table 4-2. Comparative Averages of Surface Water Bodies Within the COLAGE Test Site for December 1972 Scene

Water Body	In-Situ Data	Aircraft Data	GEMS Results	IMAGE 100 Measurements
Castaic	770	750	800	760
Boquet	610	600	630	620
Hollywood	82	80	90	85

One unexpected result of seasonal measurements of surface water areas indicated that the relative constancy versus variability of theme pixel counts could be rather readily correlated to the reservoir management for public water supply being maintained for constant (city) hydraulic pressure versus that for (regional) backup use.

\*The images in Figures 4-3 through 4-36 show the results of electronic machine analysis. They are grouped at the end of this section together with commentary that explains the processes and results.

#### 4.6 AN AGRICULTURAL PATTERN ANALYSIS IN ANTELOPE VALLEY: PHOTointerpretation Mode Study

The first use of machine analysis was made for an agricultural study in the Antelope Valley on the GEMS equipment. The analysis was done in a quick look fashion so results could be presented at the first symposium NASA held for ERTS users. The machine was operated by GE members of the study team and results were phoned to the Test Coordinator, in Los Angeles, in real time. His comments were factored into the on-going analysis in the man/machine interactive process. Subsequent passes at this area were analyzed during the course of the investigation for agricultural patterns study reported here in summary fashion.

The initial analysis was done on the ERTS E1018-18010 scene, a 9.5 inch color transparency with MSS Bands 4, 5, and 7 acquired of the LA area on August 10, 1972. The analysis on GEMS was done during half-a-day on the system. A color print of the scene was made available to the team members in Los Angeles whose visual observations and comments helped in selecting and analyzing the topics and areas reported here.

The ground truth data for the field crops for 1972 was obtained from the County Agricultural Field Representative in Lancaster, California to verify the GEMS-analyzed acreages. The RPC supplied the 1971 crop data for the Alpine Butte quadrangle (Figure 4-6) as well as the average data over a few years gathered for their Environmental Design Guide program. A later (May 6, 1973) low level aircraft slide of the area is shown in Figure 4-5.

In the application of multispectral analyses to the field of agriculture the appropriateness of the use of a priori versus a posteriori approaches can be well illustrated. The traditional agricultural problem for remote sensing is the identification and inventoring of a given species of a crop, including its state of health. With known ground truth, this problem is solved by the a priori object class spectral signature determination and searching the rest of the scene for equivalently signatured areas.

From a planner's point of view, the agricultural data of interest is not so much crop species identification as agricultural land use in the context of the surrounding land use trends. To a planner, the functional role of the agricultural subsystem in the total planning system is of primary interest. Data on the agricultural field patterns, their shapes and sizes, relative vigor of an area to ascertain viability of the activity, possible disinvestment, rate of change of areas under crop, etc., are of interest. The a posteriori cluster analysis approach becomes more useful - especially if the planting pattern is not very uniform, introducing spectral non-homogeneity.

#### 4.7 AN INTENSIVE, ITERATIVE STUDY OF LOS ANGLES URBAN CORE AREA

##### 4.7.1 INVESTIGATION FOCUS ON A NESTED SUBTEST SITE

The interest of the Los Angeles County Regional Planning Commission and the Test Site Coordinator's primary focus was on the Central Los Angeles urban core (Figure 3-8). The Core Area is a natural test site both from the photointerpreter's point of view and that of results from machine analysis. The area stands out in an ERTS image. The GEMS field of view and the IMAGE 100 full resolution data approximately coincide with the test site.

The test area was looked at temporally through the use of ERTS imagery and also multispectral data derived from aircraft underflights. A whole gamut of techniques was applied in this investigation that included preprocessing and unsupervised learning. Many findings emerged from this one mini-experiment; results are presented here chronologically in summary form. Details have been reported in periodic reports issued during the progress of the Los Angeles investigation.

A set of slides summarizing the nested investigation focus in an overview fashion is gathered in Figure 4-9.

#### **4.7.2 EARLY UNSUPERVISED LEARNING RUNS - SINGLE BAND LEVEL SLICING**

Single band slicing was attempted beginning with the first runs made on GEMS using the red, green and blue false color products, and Bands 4, 5, and 7 of the ERTS data. Each of the bands was divided into four section quartiles. Each of the bands (red, green, and blue) was divided into half and in half again, and identified in terms of percent of gray levels as: upper-most, upper and lower center, and lower-most. The bands were analyzed for data content in terms of their gray levels. Those pixels from the transparency from any one intensity level were developed at one time, and patterns emerged which were alarmed. The images were later compared by the Los Angeles County investigators with available land use information. As a result of this comparison, the locations of nearly 300 features (e.g., parks, school sites, hospitals and other large structures often with significant grassy areas around them) were verified as being reflected in the patterns yielded by GEMS analysis. In addition to these urban infrastructural features (fine structure features) some coarse structure patterns also were "manifested". The coarse structure appears to approximate broad general areas of different land use intensity and/or different environmental quality. In addition to the fine and coarse urban structural patterns, the major arterial street network was also made visible.

Calibration problems were experienced between scenes when the GEMS was used. As a result, procedures were developed to cope with the problem at a later stage of the investigations using the computer compatible tape data. A program was developed for use on the IMAGE 100 that directed the computer to slice up to eight groups of levels in each of the four bands. This program also enabled the investigators to arrive at results in a short time that would have required several passes to perform on the GEMS equipment.

#### **4.7.3 SEVEN-THEME SYNTHESIS**

The map of Figure 4-10 is the result of a multi-exposure procedure on the GEMS that identified the broad use of land in the Los Angeles urban core area. Rather than attempt to identify specific structures such as schools, or features such as shopping centers or industrial areas, the investigators attempted to classify the county in this subtest according to the intensity of land use beginning with the urban core and extending in some seven steps out to the open land areas. Classification resulted from a combination of supervised and unsupervised learning. Areas of common usage were assigned a distinctive color from seven possible colors on GEMS (Hence the number seven for total number of themes). Colors assigned to the seven themes were:

1. Red	Very intensive commercial and industrial areas
2. Green	Intensive industrial and commercial districts
3. Blue	Older multiple family residential areas; commercial and industrial uses
4. Red-Green (Gold Yellow)	Older low income single family residential, multi-unit residential, newer and/or lower intensity industrial commercial
5. Green-Blue (Turquoise)	Middle income, multi-unit apartments and low to middle income, single family housing
6. Red-Blue (Magenta)	Newer, higher quality single family housing
7. Red-Green-Blue (Cream White)	High quality residential and open space

The original synthesis was done on the GEMS with an ERTS image of Los Angeles made in October of 1972 as an input. These results were correlated with available ground truth for the Central Los Angeles area. The correlation indicates that this GEMS derived product reflects the presence of approximately 330 features, areas and street alignments which in combination portray an urban fine structure of surfaces, modes, facilities and open spaces; and an hierarchical, multidimensional coarse urban structure reflecting general patterns of use intensity and environmental quality.

The location of fine structure features is shown with reasonable accuracy but their shapes are not defined with a high degree of fidelity. Traditional land use, urban structure and relative environmental quality complexly overlapped by the above spectral themes are useful inputs to general policy formulation and large scale urban design.

Development of this 7-theme mapping technique was reported in more detail at the Sioux Falls meeting of October, 1973, and at the Second ERTS Symposium at NASA/Goddard Space Flight Center in March, 1973.

#### 4.7.4 MULTIBAND SLICING/CLUSTERING ANALYSIS

The GEMS equipment enabled the single-band slicing technique to be repeated for two bands at a time in combinations of red/green, blue/green or red/blue. A subtest was conducted in which 10 by 10 slices were chosen in each of the two bands. It would have been possible to obtain results for 100 themes, but the interactive nature of the system was used to select only those themes that were of specific interest to the investigators. Between 12 and 15 themes were selected for each band-pair and the printouts were sent to Los Angeles where the Regional Planners later made the correlative analysis. Figure 4-11A shows a selection of 12 themes from blue/red slicing/clustering applied to the downtown area of Los Angeles.

A large amount of output data was obtained, but it was time-consuming to interpret the large volume of information and establish its significance. Thus, a need arose to evaluate the multispectral and temporal characteristics of the imagery. Another motivation for this substudy was the derivation of spectral calibration, i.e., interpreting the displacement of the themes from one date to another and the interpretation of changes in ground patterns from one season to another.

There is a cluster synthesis program written for IMAGE 100, since this study was completed, that would enable this experiment to be repeated in 3 or even 4 spectral bands in conjunction. But these results would produce an unmanageable amount of data, so this investigation was limited to only two bands at a time.

#### 4.8 AN EXTENSIVE, MULTI-LOCATIONAL URBAN AREA STUDY IN LOS ANGELES AND ADJACENT COUNTIES

The objective of this substudy was the geographic extension of spectral signatures derived from the Los Angeles Urban Core to equivalent communities within adjacent counties. Results were of interest to the investigators for two different reasons: County Planners concentrated on regional environmental patterns (Figure 3-7), while the GE members of the team were concerned with signature extension as a technique under both undersupervised and unsupervised learning conditions.

The areas considered within the county in the investigation included Long Beach, San Fernando Valley, San Gabriel Valley, Glendale/Burbank, Newhall/Valencia, and Palmdale/Lancaster. Areas considered outside the county were: the Oxnard Plains in Ventura County, Southern San Joaquin Valley/Bakersfield in Kern County, and such bordering areas as Orange and San Bernardino Counties.

This unsupervised learning approach was an extension of the single-band slicing technique described in Section 4.7.4 for two-level slicing/clustering in 10 x 10 slices using the combination of red/green, red/blue and blue/green. ERTS transparencies from October 1972 and March 1973 of Los Angeles were used as inputs to the GEMS equipment. The analysis was concentrated on two items:

1. How spectral classes corresponded spatially for a given sensor?
2. How did these classes shift between the spring and fall?

As before, calibration was a problem for both transparencies of the same date and between the two dates. This difficulty resulted in relative analysis in spectral terms, so that interrelations among the classes (in the Los Angeles Core Area, for example versus those in the San Gabriel Valley) were considered and not the absolute intensity levels of the respective classes. A preliminary re-run of this approach was made on the IMAGE 100 with tape data. A halftone output from one of these themes is shown in Figure 4-11.

Similarly, seasonal comparison was focused on evaluating, for areas of similar nature, the differences in themes both spectrally and spatially. Thus, there was a thematic correspondence between the highly developed areas of Los Angeles and similar areas in the San Fernando Valley. The correlation was explored for subclasses such as parks or industrial areas within the urban cores.

The outputs from this substudy showed very broad, general land (surface) cover classes. The volume of outputs was so great that resources were not available to fully verify the validity and meaning of all data obtained both in the alphanumeric theme printouts offline and the multiband spectral histograms online from the GEMS analyses. Reconnaissance verification indicated the general patterns that appear consistent with what is known about regional spatial organization and patterns that do not appear consistent. However, not enough specific ground truth was readily available to either verify or invalidate the preliminarily apparent in consistent patterns.

#### 4.9 TRAINING/TESTING ANALYSES OF RESIDENTIAL AREAS

The supervised learning approach was used in this analysis of residential areas in Los Angeles. The procedure used was to assess differences in the types of residences with the application of signatures from the west central area of Los Angeles to other residential areas both within and outside the County but within the ERTS frame. The classes of housing for which signatures were obtained included both single family residences and multiple unit dwellings. The analysis tended to corroborate the investigator's intuition in training and classification, but it again resulted in so much data that an intensive, iterative investigation was not possible within the project resources. However, it was concluded that broad signature extension, together with intensive ground truth within the area, could be used to devise procedures that would enable general identification of residential classes in the Los Angeles area over an ERTS scene.

#### 4.10 FEW PIXELS SPATIAL AND TEMPORAL ANALYSIS OF MINI-SITES WITHIN THE LOS ANGELES TEST SITE

##### 4.10.1 SPECIFIC PROBLEM/INTEREST AREAS

In this substudy, specific mini-sites were selected for intensive analysis. Because of the digital outputs from IMAGE 100, 4-band analyses were possible, so some of the tests originally run on GEMS were re-run on IMAGE 100 for a comparison of results. The spectral range of the data was limited to 15 levels on GEMS, whereas 64 levels were possible on IMAGE 100. The split-screen feature of IMAGE 100 was used for the first time in some portions of this substudy. Sites selected for testing included:

1. Grading Sites
2. Sheep Creek Fan
3. The Bouquet Reservoir
4. Wilshire Country Club
5. Marina del Ray

#### 4.10.2 GRADING SITES

Grading sites which are often indicative of new urban construction, in the Los Angeles area were looked at through photointerpretation techniques described in Section 3. These investigations served to point out the degree to which the urban area was encroaching on the non-urban areas. The purpose of this machine analysis was to identify the grading sites within the County and to study their spectral characteristics. See Figures 4-12 through 4-14.

As a general rule, it was possible to identify the grading sites since the signatures in the training areas fell within a narrow range. When the training areas included sandy beaches, such as along the coast, that exhibited similar spectral characteristics as the grading sites, the only way these areas could be separated was through the interaction of the investigator with the machine.

#### 4.10.3 SHEEP CREEK FAN

The full extent of the Sheep Creek Fan in Antelope Valley near the Los Angeles-San Bernardino Counties was noted for the first time by the County investigators using ERTS imagery. The U2 imagery of the Fan (covering an area 15 by 15 miles) was used to select the training sites for this test. These results were sent to an area geologist who commented upon the themes within and around the Sheep Creek Fan vis-a-vis their utility for preliminary exploration. See Figures 4-15A through 4-15G.

#### 4.10.4 BOUQUET RESERVOIR

This area had been identified as part of the tests conducted on GEMS for surface water bodies area measurements in the Los Angeles Test Site earlier. The purpose of this analysis was to study the detailed structure of the reservoir using the IMAGE 100. A temporal analysis was also conducted as part of these tests. Figures 4-16 and 4-17 show aerial ground truth for visual comparison with machine analyses results.

This investigation represents the first time registration of an aircraft image and an ERTS image was attempted (see Figure 4-18). The aircraft image was derived from a U2 flight in March 1973, and the ERTS image was made within a few hours of the aircraft image on the same day. The registration procedure is explained in Appendix B which discusses ERTS data geometry. Primarily, registration was accomplished by repeating an ERTS pixel in terms of a number of TV pixels using such features of the Bouquet Reservoir as its outline and islands within the Reservoir for manual registration. Machine-aided registration programs have been developed on the IMAGE 100.

The number of classes in this study could have been as large as the number of training sites selected by the investigators, and the data that resulted from the analysis often exceeded the ground truth of the area that was available.

Another feature of this investigation was the use of the difference in temporal coverage using images from two different dates with the use of the split screen mode. The upper part of Figure 4-19 is an image of the Bouquet Reservoir made on October 1972, and the lower part of Figure 4-19 shows an image of the same area in March 1973. A pixel by pixel analysis of these images reveals the fact that the sensors in the spacecraft do not start the scanning sequence at the same point on the ground in view of the relative displacement of the spacecraft relative to the ground. Hence the same area on the ground is instantaneously viewed in a different position and covered in a different sequence. This fact is demonstrated by a review of both images at the same time. It will then be noted that the islands will be enhanced more in one image than in the other and the outline of the Reservoir is more distinct in one image than the other: pointing up the necessity for border pixels consideration generally and intra-pixeluar analysis specifically.

#### 4.10.5 WILSHIRE COUNTRY CLUB

The Wilshire Country Club was selected because of its peculiar shape and orientation in ERTS scenes and because of its relative accessibility for analysis. The initial point of interest was a comparison of the registration from two different images taken on the same date; one from an aircraft and the other from the ERTS satellite. The images were derived from the 14th March 1973 coverage. Figure 4-21 illustrate this aspect of the problem set up sequence. The reader can notice the road through the Country Club, the club house and fairways on the U2 images and these features are brought out in the ERTS data in discernable fashion for classification. Figure 4-22 shows the results of two training and classification runs.

Seasonal analysis could best be done on the split screen. In Figure 4-23, the left half was read from the October 1972 data feature of the IMAGE 100 and the right image was obtained in March 1973. Comparing these images pixel by pixel, it can be seen that the March scene is better visible than the December one, when compared in the raw format. Aircraft underflights data for these dates qualitatively corroborates this relative illumination. The utility of normalization procedure in IMAGE 100 is seen readily by comparing the identically exposed and processed images in this figure. The principal difference between the two dates was the sun illumination in addition to any physical changes on the ground itself, assuming sensor-platform calibration was made. The combination of all these factors resulted in the differential signatures and theme-alarms seen in Figure 4-24 where training sites were attempted to be maintained as close to each other ("same") as possible, given the intrinsic variation in the original data acquisition owing to the relative phase of digitization on the ground itself between the two ERTS passes.

Ground truth requirements, including atmospheric effects to thoroughly evaluate the differential temporal analysis results shown here, were beyond the resources of the investigation. Nor did the investigators have the wherewithal to follow up on the various recreational areas monitoring within the County, but the potential temporal advantages of monitoring for regular maintenance or vegetative disease detection could be readily appreciated by the reader. Such an effort would have to be defined and proposed in a separate, rather extensive effort.

#### 4.10.6 MARINA DEL REY AREA

The Marina del Rey is a distinctive feature of the Santa Monica Bay area of Los Angeles (Figure 4-25). This site was chosen for considerations of geometric simplicity temporal registration. The separate arms represented by the docks and piers could be analyzed pixel by pixel, Figure 4-26. The split screen mode was again used to look at four different images of the area taken in August and October of 1972, and January and March of 1973. These are shown in Figure 4-27. The interest in this substudy was generic in terms of techniques and development of histograms with only visual comparison of ground truth.

#### 4.11 A MAJOR SUBSTUDY OF HOUSING CLASSIFICATION FROM ERTS TAPE DATA USING IMAGE 100

The objective of this substudy was to test the capability of ERTS data as machine-analysed for classifying land cover compared with a) the system in use by the Los Angeles County Regional Planning Commission to make equivalent land use classifications and b) a scheme developed from concurrent aircraft imagery for direct input and evaluation elsewhere. The effort required a substudy for each separate class of land use, but because of the limited time that could be devoted to this effort, the only land use class investigated here was that of housing types in the residential areas of Los Angeles County and vicinity.

This substudy marked the first time ground truth was derived from multispectral imagery onboard aircraft, in contrast with the other substudies. Ground truth, both for input preparation and output evaluation, was derived from maps and charts supplied by the County.

Supervised learning was used in this subtest, and the IMAGE 100 was used to train on the residential test sites which were selected from aerial photographs. The test sites were homogeneous with respect to their distinguishing housing types and structure. Following the training procedure and electronic analysis, color enhanced themes, which were representative of the residential class, were made of the entire field of view on the TV monitor. Slides were made of these themes and compared with dedicated land uses as indicated on Los Angeles base maps as well as with the classification scheme for input preparation.

##### **4.11.1 DETAILED METHODOLOGY OF INPUT PREPARATION AND MACHINE ANALYSIS**

The primary residential classifier used was "dwelling units per acre". This was expanded to include: floor area ratios, building coverage, and net green space values. (A distinction was made here between green space and open space.) Two groups of secondary classifiers were designated. The first described community structures such as street systems, single or double loading and the existence of rear yard servicing. The second group described predominant features of the individual lot; for example, roof tones, which is a consistent and recognizable pattern in most Los Angeles developments, the frequency of swimming pools, and laneway characteristics such as single/double, asphalt/concrete that lead to front or rear yard garages.

Test sites were selected from aerial photography from U2 Under-flights 73-036 of March 14, 1973 at a scale of 1:32,000, see Figure 4-28. The training sites were recorded by ink drawings on tracing paper. See Figure 4-29. It was anticipated that these photos would have to be reduced appropriately (See Figure 4-30) to register with the digital data display on the TV monitor, but it was found unnecessary to go through such a referencing procedure because of the very high quality of the digital data display (See Figure 4-31). All test sites were thus located easily.

IMAGE 100 has the capacity to digitally enlarge any given field of view. The scale factors chosen in this sub-test were 3 in cross-track and 4 in down-track directions, and represented a tradeoff between the quality of detail required to train by and the overall size of the field of view required in the results.

Themes are areas which appear on the TV monitor color enhanced; Figure 4-32 is typical although the reproduction here is in black and white. Hopefully, these themes represent classes having similar spectral properties, but such conclusions are the result of the evaluation stage. After a site was selected for analysis, it was identified by means of an electronic cursor (the white rectangle in Figure 4-32). A theme was produced following the execution of these two routines:

1. One-dimensional histograms were constructed for each channel; these gave the upper and lower limits in the reflectance scale and the distribution of pixels within the range bounded at the limits. The limits are first set by choosing a threshold for pixel counts but may be adjusted later if a more selective or less selective reflectance range is desired. (See Figure 4-33.)
2. The second routine provided four-dimensional histograms. Color space was divided into cells according to criteria prescribed by the analyst for the number of divisions in each of the four reflectance scales derived during the first routine. The cells, which contribute to the final spectral signature upon which a color enhanced theme was generated, were chosen according to the number of pixels they contained, per cell, in relation to a lower limit or threshold (see Figure 4-34).

When the two routines were completed, a spectral signature was established. All pixels having similar spectral properties over the entire field of view were color enhanced to provide the theme.

Three parameters influenced the generation of themes:

1. The upper and lower limits in the 1-D histograms
2. The number of divisions per channel in the 4-D histograms
3. The threshold for pixel counts in the 4-D histograms

Experimentation during analysis, an advantage of IMAGE 100, was required in the choices made for each parameter. Through an iterative process of changing inputs and checking monitor results at selected locations for which ground truth information does exist (the selected test sites for example) many themes were generated with varying results. A 16-level, 4-D histogram tended to be too inclusive: yet a 64-level, 4-D histogram was too selective. The objective was to produce as discrete a spectral signature as possible, representative of the class that the user has selected to define. One of the test sites was in San Fernando Valley. The local community has a great range of housing density classes. The training sites are comprised of areas of detached houses with an estimated average density of 1.3 units/acre.

After preliminary analysis, the themes selected for evaluation were:

Theme 1: 1-D limits were established, a 4-D threshold of 2 prescribed and a 64-level, 4-D histogram run

Theme 2: 1-D limits were narrowed, the 4-D threshold kept at 2, and a 32-level 4-D histogram run

Theme 3: 1-D limits were held, the 4-D threshold changed to 38- and the 32-level, 4-D histogram repeated

Theme 4: 1-D limits were broadened, the 4-D threshold changed to 2, and the 32-level, 4-D histogram repeated

Theme 5: 1-D limits were established, a 4-D threshold of 2 prescribed and a 16-level, 4-D histogram run

Theme 6: 1-D limits were established, a 4-D threshold of 2 prescribed and an 8-level, 4-D histogram run

The outputs obtained are pixel counts per theme. Results of converting the acerages are shown in Table 4-3.

#### 4.11.2 EVALUATION OF DERIVED THEMES AGAINST DEFINED CLASSES

The themes displayed on the monitor were recorded on slides and later projected onto Los Angeles County land use maps (see Figure 4-35) and registration was attempted. A dot planimeter was used to obtain theme and class area measurements from the overlayed trace. Results of these analyses are shown in Table 4-4 for the test site in San Fernando Valley. Each column of the chart, headed by a color, represents a theme; for this test site all the six themes were evaluated (Figure 4-36).

The first column in Table 4-4 gives as a percentage of the total the land uses. In each theme column the figures under "a" give the area of the land use class which is color enhanced as a percentage of the total area or theme. In each theme column the figures under "b" give the area of the land use class which is color enhanced as a percentage of the total land area for the class.

There was very little available machine time and the sample size was therefore small. For evaluation purposes it was felt that more reliable results using U2 photography classification scheme was achieved, although the choice then would tend to weaken the previously defined purpose of working with a user agency and their land classification system.

Table 4-3. COLAGE IMAGE 100 Housing Study

Test Site No. 1 - San Fernando Valley  
Raw Data Observations

Land Use Classification		Theme					
		Purple	Yellow	Brown	Lt. Blue	Dr. Blue	Black
Single-family residential	(L)	918	827	683	528	417	189
Multiple-family residential	(M)	3	2	1	1	2	0
Commercial	(C)	33	11	8	4	4	1
Recreational	(R)	11	4	6	8	7	1
Public	(P)	24	27	21	11	15	5
Services	(S)	89	29	21	30	27	23
Open Space	(O-1)	109	66	56	35	29	10
Vacant	(Z-1)	4	3	2	1	1	1
Area Alarmed		1,081	969	798	618	502	230
Total Area		1,360	1,435	1,394	1,470	1,394	1,344

Table 4-4. Housing Test Site No. 1

## San Fernando Analysis Summary

Theme		Purple		Yellow		Brown		Lt. Blue		Dk. Blue		Black	
Area Alarmed %		79.5		67.5		57.2		42.0		36.0		17.1	
		(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Single-Family Residential	1,020.2	76.6	84.9	82.1	85.3	74.0	85.6	61.1	85.4	47.2	83.1	37.3	82.2 16.9
Multiple-Family Residential	5.5	0.4	0.3	50.0	0.2	33.3	0.1	16.7	0.2	16.7	0.4	33.3	0.0 0.0
Commercial	42.9	3.2	1.1	70.2	1.1	23.4	1.0	17.0	0.6	8.5	0.8	8.5	0.4 2.1
Recreation	25.6	1.9	1.0	39.3	0.4	14.3	0.8	21.4	1.4	28.6	1.4	25.0	0.4 3.6
Public	31.9	2.4	2.2	68.6	2.8	77.1	2.6	60.0	3.0	31.4	3.0	42.9	2.2 14.3
Services	88.5	6.6	2.0	91.8	3.0	29.9	2.6	21.6	5.4	30.9	5.4	27.8	10.0 23.7
Open Space	125.0	9.4	8.1	81.3	6.8	49.3	7.0	41.8	5.8	26.1	5.8	21.6	4.3 7.5
Vacant	4.6	0.3	0.4	80.0	0.3	60.0	0.3	40.0	0.2	20.0	0.2	20.0	0.4 20.0
Total	1,332.3	100.0	100.0		100.0		100.0		100.0		100.0		100.0

(A) Area Alarmed as a % of the Theme, e.g., Area Identified in Purple (79.5% of Scene)

(B) Area Alarmed as a % of the Class, e.g., Land Use

Of much more interest to planners is a concept which the COLAGE investigators have proposed at NASA symposia involving development intensity. In this approach, land is classified according to its natural or man made ground coverage, and ranked according to the properties of each. This information can have enormous impact upon policy and standards for land use when it is used by imaginative planners.

Black and white prints of 35mm color slides are grouped at the end of this section as Figures 4-3 through 4-36. These illustrations are primarily displays that resulted from the interactive color TV monitors on the GEMS and IMAGE 100 together with a few corroborating aircraft and other reference data.

This sequence of illustrations is self-standing as a set elaborating upon the elements of machine analysis referred to in Figure 4-1. ERTS data characteristics, such as synopticity, periodicity, multispectrality, and resolution and content, are brought out. The full range of system features for GEMS and IMAGE 100 are presented, including: preprocessing, mode/transformation, supervised and unsupervised classification approaches, user-supportive, and techniques/displays, etc. A wide variety of applications/disciplines/problems, listed in Table 4-1, are illustrated by this imagery.

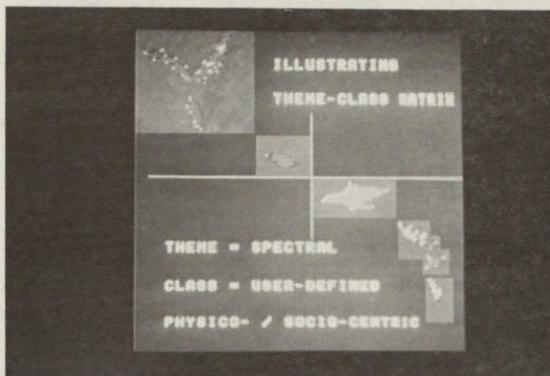


Figure 4-3A. Illustrates the definitions of and distinction between a class and a theme; a sub-theme has been acquired.



Figure 4-3B. By synthesizing a series of subthemes, classes of user interest have emerged for bodies 1, 2, 4, 5 and 6. Linear enlargement is 2X; arial enlargement is 4X.



Figure 4-3C. Another set of themes synthesized yielded the class of water in the Boquest Reservoir. The themes in turn represent the spatial location of "pixels" viz picture elements having a common spectral signature.



Figure 4-4. Surface water body area measurements on the GEMS using color composite transparency. In contrast with the tape data analyses of the Figure 4-3A when all four bands of data were used, here only the standard three bands (viz, 4, 5, and 7) were used from source data.

Figure 4-4A. Illustrates a "Training Site" and signature acquisition for it in three dimensions.

NO.  
 DETECTED SIGNATURE LIMITS  
 1 2 3  
 MIN 0.00 6.24 15.60  
 MAX 100.00 34.32 65.52  
 NUMBER OF CELLS: 1 9 16  
 HISTOGRAM ACQUISITION READY  
 TYPE 'GO' TO PROCEDE  
 ALARM TOTALIZER = 1.92%  
 BYN. ALARM TOTAL = 62.13%

Figure 4-4B. "Thematization" per previous signature across the Castaic Reservoir After Bay. Note that not all the water is covered in a single theme.

COLA ERTS SCENE 1108-18014-7  
 NOV 8 1973 BULK MSS  
 SURFACE WATER BODIES  
 AREA MEASUREMENTS 263  
  
 MAXIMUM ZOOM  
 CASTAIC RESERVOIR  
 DECIMAL RDG SVA 8267.8233,  
 8308

Figure 4-4C. Result of multiple sub-theme synthesizing for:

Figure 4-4C. i) Castaic Reservoir

COLA ERTS SCENE 1108-18014-7  
 NOV 8 1973 BULK MSS  
 SURFACE WATER BODIES  
 AREA MEASUREMENTS 263  
  
 GEMS MSMNT 1895 UNITS  
 10000 UN/NSOM  
 MAXIMUM ZOOM .75 STSOM  
 CASTAIC AFTER BAY 160\_ACRES  
 DECIMAL RDG SVA 1884, 1907  
 GROUND TRUTH 37.24 ACRES ?

Figure 4-4C. ii) After bay water area measurement.



Figure 4-4D. Ground Truth by light aircraft underflight.  
Image of Castaic Reservoir After Bay.

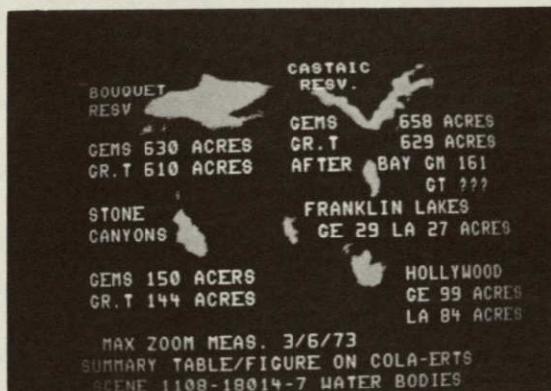


Figure 4-4E. Summary tabulation of surface water bodies area measurements on the GEMS for one date.

ORIGINAL PAGE IS  
OF POOR QUALITY

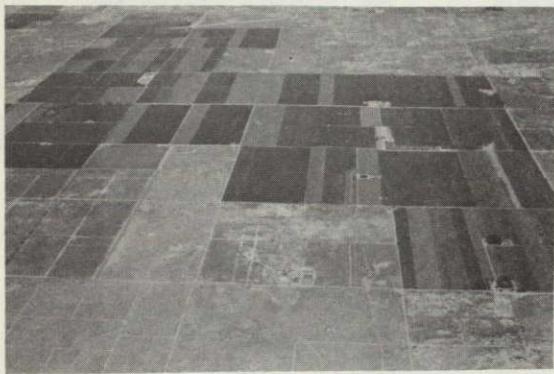


Figure 4-5. 35mm Kodachrome transparency of Dancing Dog area in Antelope Valley taken from a light aircraft at low level.

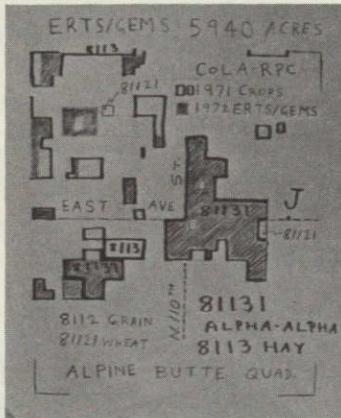


Figure 4-6. Preliminary ground data for agricultural pattern study.



Figure 4-7A. Display of 9x9 mile area in eastern Antelope Valley, obtained by GEMS analysis of an ERTS-1 image of Los Angeles. The grid is a superimposed map of the major section line roads in this area. The road intersection near the letter "D" is East Ave. and North 100th St. Based on Preliminary ground truth data, the superimposed pink area represents alfalfa fields under irrigation; the pink area represents 3.6% of the scene, or 1870 acres.



Figure 4-7B. A GEMS normalized display of the same area shown in Figure 4-7A. This enhancement aids the GEMS operator in identifying and interpreting various objects in the scene, for example the field structure and the difference between crops are more apparent after normalization. The dark blue fields are grass and the reddish brown area is alfalfa.



Figure 4-7C. GEMS display of the same area in Figure 4-7A. In this scene the irrigated alfalfa is superimposed in white and the total cultivated area is shown in white and purple. The total cultivated area is 12.3% of the scene, or 6400 acres.



Figure 4-8. An IMAGE 100 themes display with classification in various spectral space transformations.

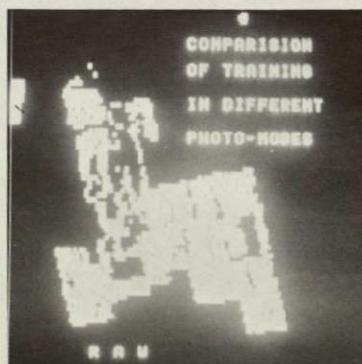


Figure 4-8A. An IMAGE 100 display of the base data in standard band color combination.

Figure 4-8B. Raw data as normally read in.

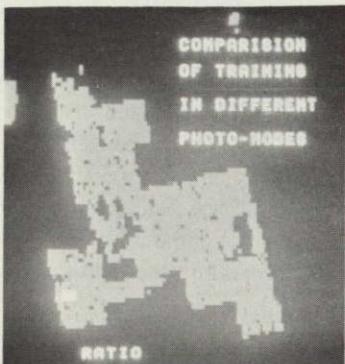


Figure 4-8C. Rational Data with:

$$\text{Channel 1} = \frac{\text{Band 4}}{\text{Band 5}}$$

$$\text{Channel 2} = \frac{\text{Band 5}}{\text{Band 6}}$$

$$\text{Channel 3} = \frac{\text{Band 6}}{\text{Band 7}}$$

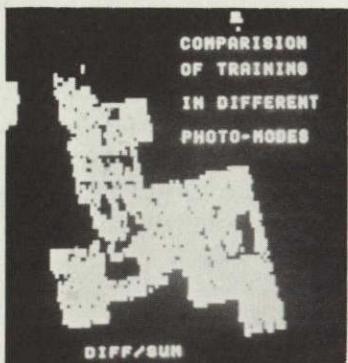


Figure 4-8D. Differences/Sums with:

$$\text{Channel 1} = \frac{\text{Band 4} - \text{Band 5}}{\text{Band 4} + \text{Band 5}}$$

$$\text{Channel 2} = \frac{\text{Band 5} - \text{Band 6}}{\text{Band 5} + \text{Band 6}}$$

$$\text{Channel 3} = \frac{\text{Band 6} - \text{Band 7}}{\text{Band 6} + \text{Band 7}}$$

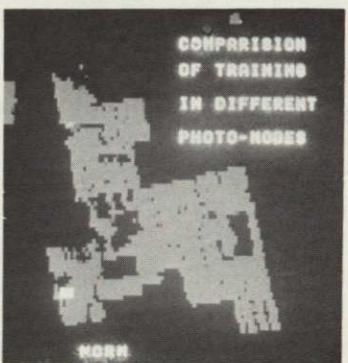


Figure 4-8E. Normalized data:

$$\text{Channel 1} = \frac{\text{Channel 1}}{\text{Channels } (1 + 2 + 3 + 4)}$$

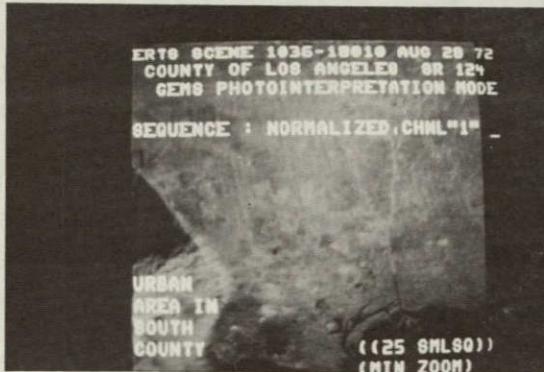


Figure 4-9. Views of the Los Angeles Urban Area Processed by GEMS and IMAGE 100.

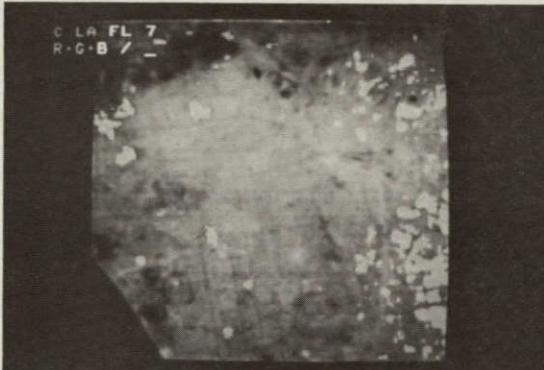


Figure 4-9A. Minimum zoom covering 25 nm square. Long Beach harbor and other details are brought out in this data normalized on the GEMS.

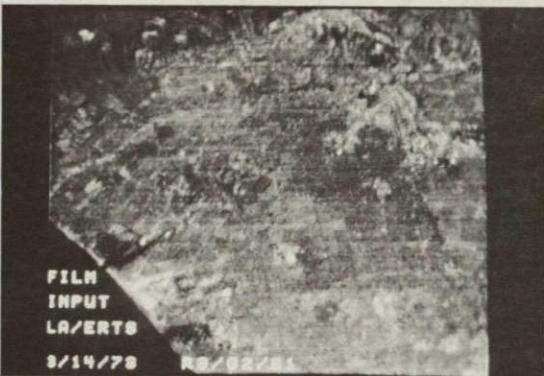


Figure 4-9B. Typical study area around downtown Los Angeles on the GEMS at typical zoom.



Figure 4-9C. Standard color transparency for March 14, 1973 digitized via scanner input into IMAGE 100.

Figure 4-9D. IMAGE 100 MSS Bulk Computer Compatible Tape covering 500 x 500 ERTS pixels over same size area on TV



Figure 4-9E. Aspect ratio corrected view on IMAGE 100 ground area of 15 nm square for same date.



Figure 4-9F. Hadamard Transformation of previous image in spectral space.



Figure 4-9G. Fall and spring views in split screen fashion: tape load coordinate adjustment for standard reading-in/display.



Figure 4-9H. Rationed image display from individual bands viewing the October 1972 data. Dropout lines are from Band 6 (MSS 3) not normally seen in the standard display of Figure 4-9G.

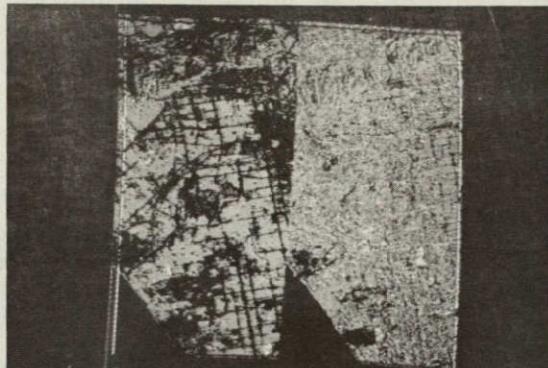


Figure 4-9I. Fall signature for parks and golf courses.



Figure 4-9J. Having ascertained the approximate registration starting points, the October Tape No. 3 is read in showing Band 5 and tape edge.



Figure 4-9K. Band 5 of October 21, 1972 scene read on Channel 1 of IMAGE 100 for approximate temporal registration.



Figure 4-9L. Band 7 of same date read on Channel 2.



Figure 4-9M. Band 5 of March 14, 1973 scene read on Channel 3.



Figure 4-9N. Band 7 of March 14, 1973 read into Channel 4.



Figure 4-9O. Resulting temporally registered full scene/two-bands image, displaying Channels 1, 2, and 4 with red, green and blue.



Figure 4-9P. Another view (Channels 3, 2 and 1) on red, green and blue. Since this experiment, a registration procedure for eight or sixteen bands/channels into half or quarter core has been developed.

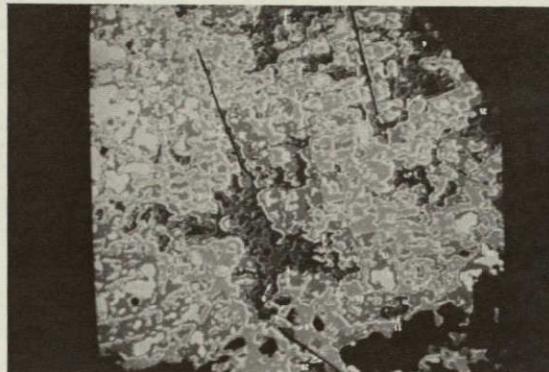


Figure 4-10A. Seven-theme land cover/use map of Los Angeles derived from GEMS. (Keyed numbers identify separate areas in this report to reduce the cost of printing in color.)



Figure 4-10B. Eight-theme land cover/use displayed on IMAGE 100. Theme 1, low density residential area.

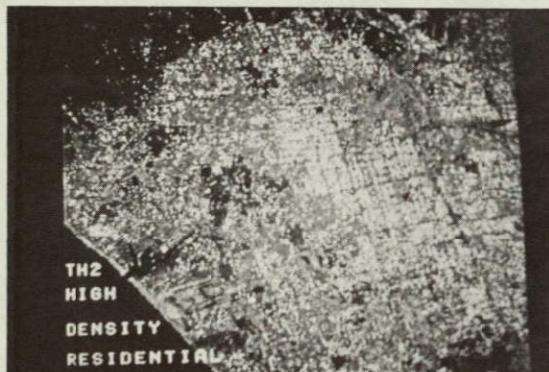


Figure 4-10C. Eight-theme display on IMAGE 100. Theme 2, high density residential area.



Figure 4-10D. Eight-theme display on IMAGE 100. Theme 3, water in Santa Monica Bay.



Figure 4-10E. Eight-theme display on IMAGE 100. Theme 4, heavy commercial area of the Los Angeles Business District shown enlarged 4X by "window" mode display.



Figure 4-10F. Eight-theme display on IMAGE 100. Theme 5, heavy industrial area.

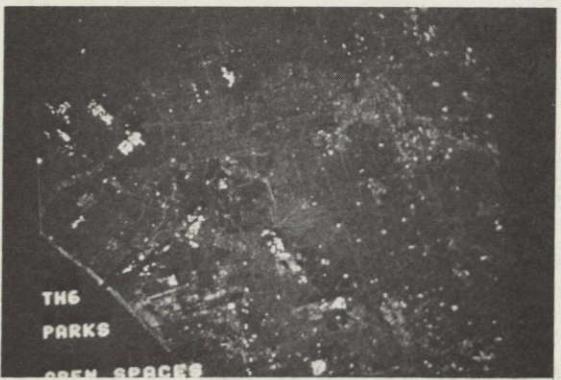


Figure 4-10G. Eight-theme display on IMAGE 100. Theme 6, parks, cemeteries and open spaces.

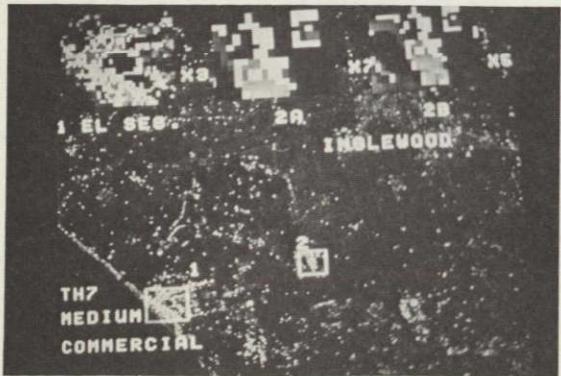


Figure 4-10H. Eight-theme display on IMAGE 100. Theme 7, medium commercial area; window display at various scales are identified.



Figure 4-10I. Eight-theme display on IMAGE 100.  
Theme 8, mountainous terrain: Santa Monica  
Mountains and Baldwin Hills.



Figure 4-10J. Eight-theme display on IMAGE 100.  
Eight-theme composite of the themes 1 through 8.

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Figure 4-11A. Thematic map of downtown Los Angeles: alphanumeric printout from GEMS

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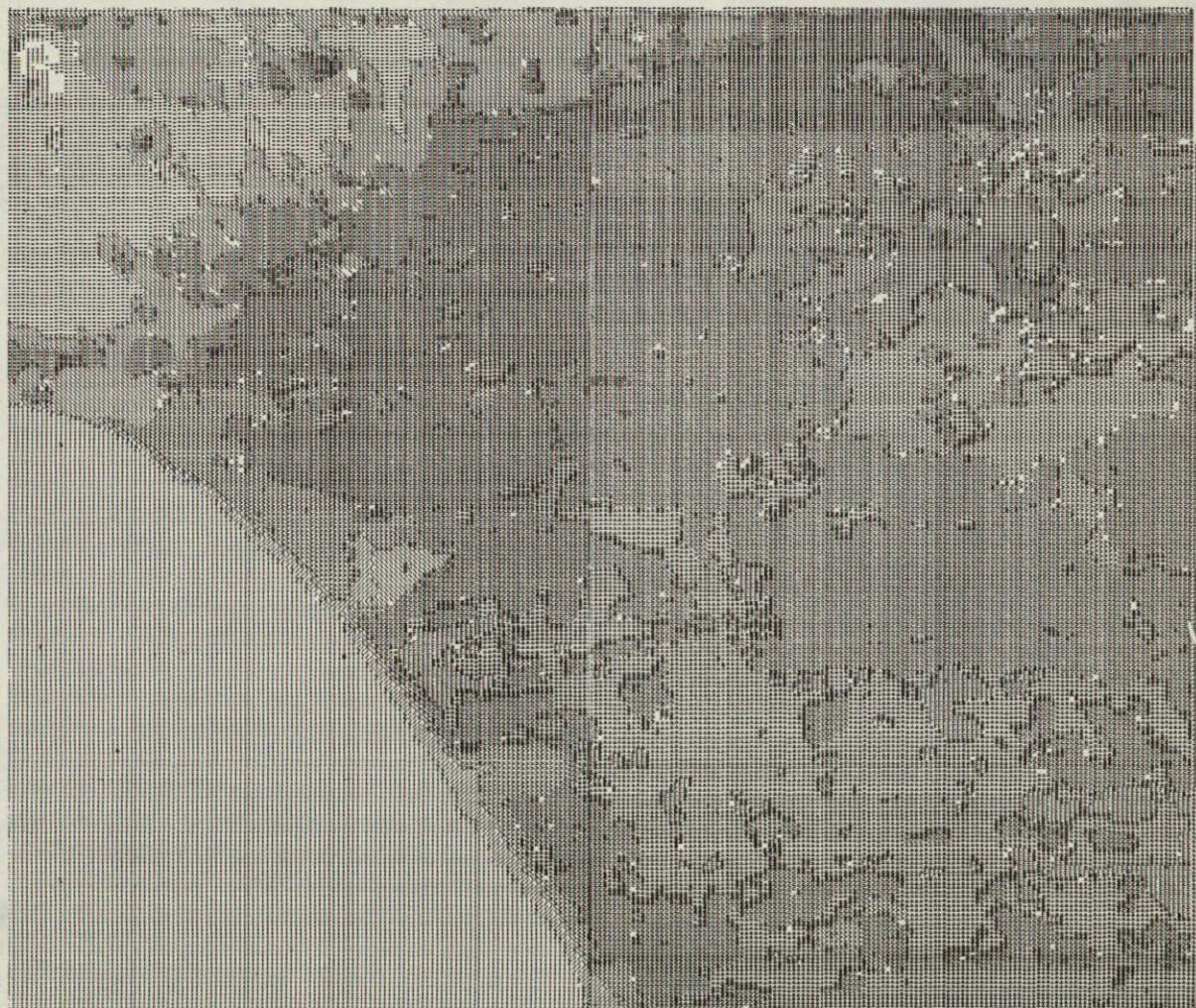


Figure 4-11B. Thematic map of Los Angeles area vegetation: halftone printout from IMAGE 100



Figure 4-12. A Grading Site off Malibu Beach.



Figure 4-12B. Classified theme on GEMS. A U2 image at 1:128,000 scale was used to compare with alarm.

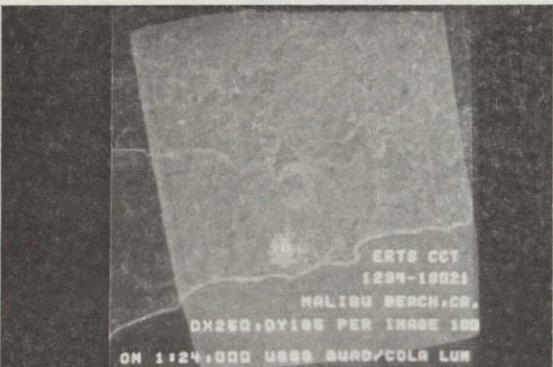


Figure 4-13. The Malibu Beach grading site read from the March 1973 ERTS tapes showing coastline registered with a USGS quadangle map ditzitized via the scanner input on IMAGE 100.



Figure 4-14. Malibu Beach grading site flown over on May 5, 1973 in a light plane using a hand-held 35mm camera with Kodachrome film.



Figure 4-15. Illustrating the Interactive Signature Acquisition Mode on GEMS as applied to the Sheep Creek Fan classification.



Figure 4-15A. Training site signature in three dimensions, parallelepiped mode.



Figure 4-15B. Alarm for the gross theme for parallelepiped in spectral space.



Figure 4-15C. Composing signature from cells in spectral space with discrete alarm synthesis for cells 1 through 9, highest densities.

Figure 4-15D. Cumulating subthemes 1 through 15 from top 15 populous cells in spectral space.



Figure 4-15E. Grouping 2 of mini-themes.



Figure 4-15F. Grouping 3 of mini-themes.



Figure 4-15G. Cumulative alarm of 1 through 5 groups of signatures/themes. A geologist in Southern California, also an ERTS investigator, was sent intermediate sets of these step-wise themes. On-line, they might have selected different groupings.

C-2

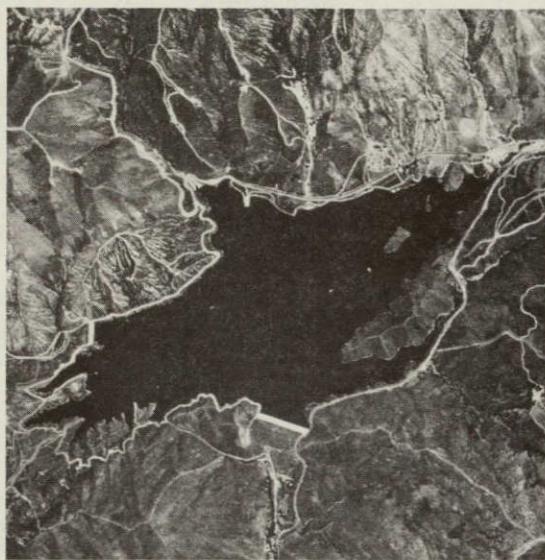


Figure 4-16. U2 Orthogonal views of Bouquet Reservoir.



Figure 4-16A. December 14, 1972 image from Flight 72-215. Original image was at a scale of 1:128,000.

Figure 4-16B. March 14, 1973 image original at a scale of 1:32,000. Note the smaller islands visible in the March image; also the water boundaries differ between the December and March images.



Figure 4-17. COLAGE flight in a light aircraft showing an oblique view of the Boquet Reservoir on May 5, 1973. 35mm Kodachrome film was used.

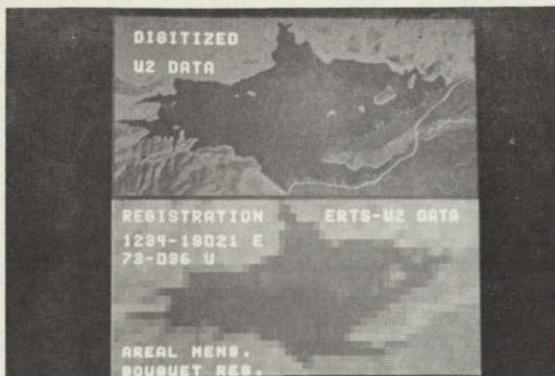


Figure 4-18. Registration of an ERTS tape-read image with digitized U2 image.



Figure 4-18A. Split screen display used to check the scale/orientation match.

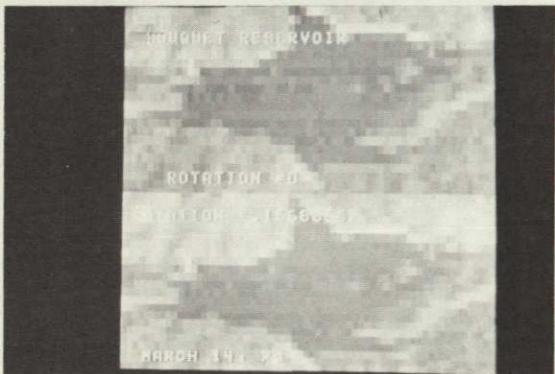


Figure 4-18B. Overlay display at a larger, matched scale. Orientation is determined by spacecraft scan data.

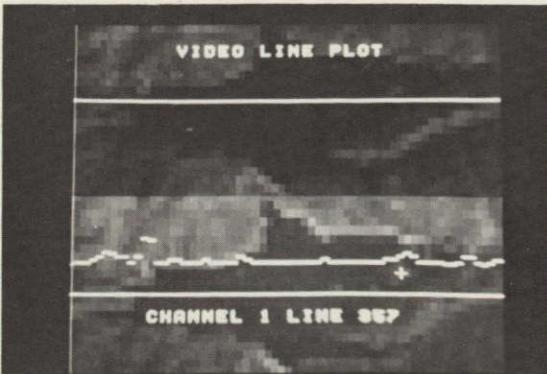


Figure 4-19. Illustrating earth's rotation correction applied to the tape-read image. Note that proper de-skewing had to be applied for full registration.

Figure 4-20. Diagnostics for temporal change detection. December 14, 1972 CCT was loaded in the upper half and the March 14, 1972 CCT was loaded in the lower half of the screen.

Figure 4-20A. Densitometer trace through corresponding scan lines covering approximately the same ground cells.



Figure 4-20B. Densitometer trace through corresponding scan lines covering approximately the same ground cells.



Figure 4-20C. Two-dimensional histograms for equivalent ground training sites can yield further insight into classification.



Figure 4-21. Few pixel problem set-up procedure for Wilshire Country Club analysis.



Figure 4-21B. Display of preliminary digitized images from U2 frames: left, color infrared; center, true color; right, high resolution black and white.



Figure 4-21C. Re-digitization of the color IR image for ERTS tape image overlay adjustment.

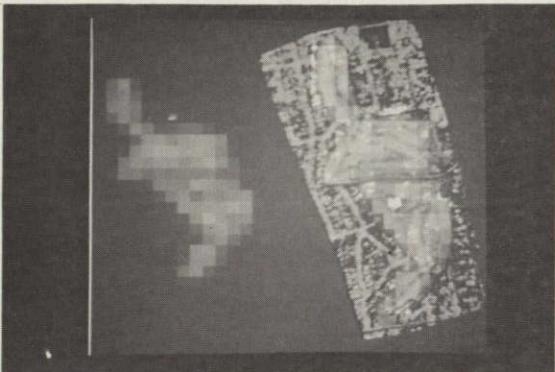


Figure 4-21D. Illustrating earth rotation de-skew and x-y aspect ratio correction: left, uncorrected, unrotated; right, corrected registerable.

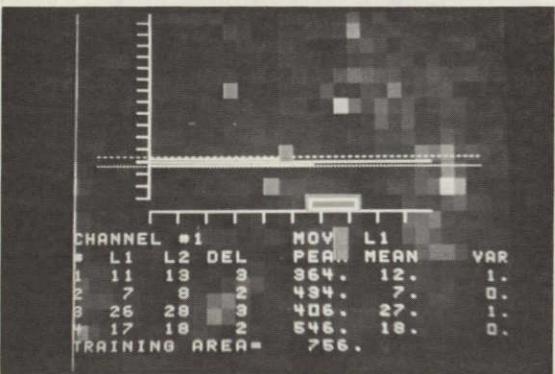


Figure 4-22. Four-dimensional spectral signature acquisition and classification of Wilshire Country Club.

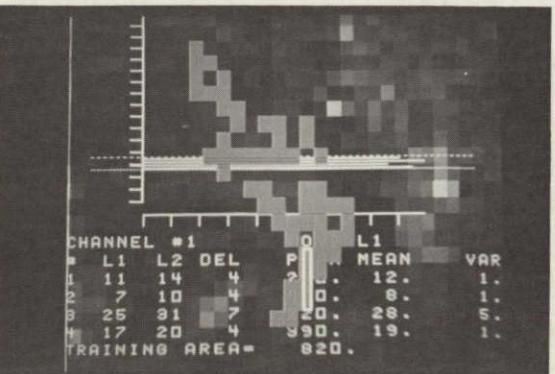


Figure 4-22A. Theme 1 for training site east of club house.

Figure 4-22B. Theme 2 for training site south of club house. Histograms for Channel 1 are displayed with limits for all four channels listed.



Figure 4-23. Temporal preprocessing for seasonal analysis of Wilshire Country Club.

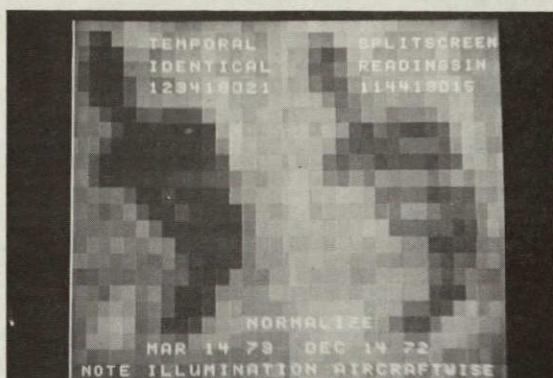


Figure 4-23A. Raw data in standard format. Sun angle: December elevation =  $26^\circ$ , azimuth =  $152^\circ$ ; March elevation =  $43^\circ$ , azimuth =  $136^\circ$ .

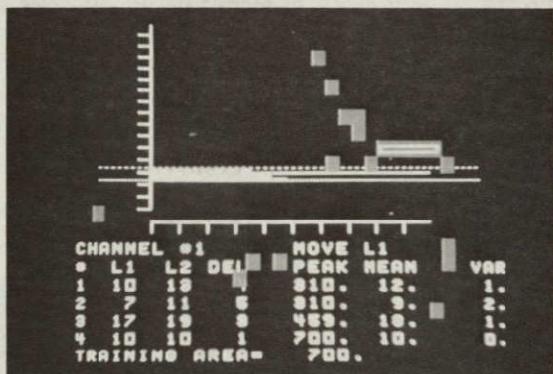


Figure 4-23B. Normalization transformation over all four bands uniformly over the entire field of view. Note that the December image is better analyzed in this mode in contrast to the raw data mode.

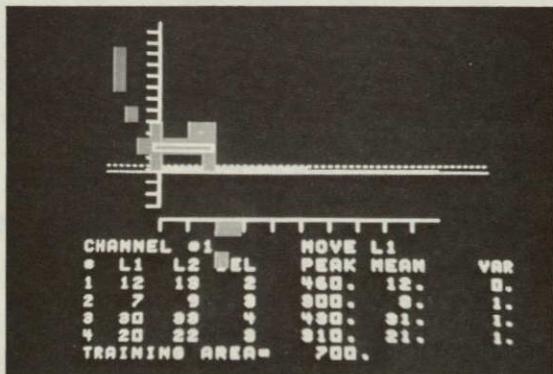


Figure 4-24A and 4-24B. Temporal change determination at close to same site locations. Themes are localized per season.

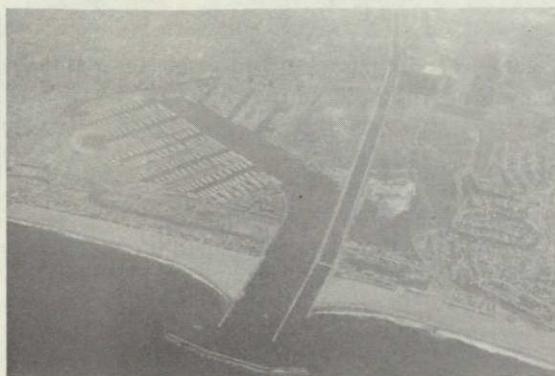


Figure 4-25. Marina del Ray seen from a light plane just after takeoff from the Santa Monica Airport on May 5, 1973.



Figure 4-26. An ERTS image of the Marina del Rey for March 14, 1973, covering 64 pixels along scanline (x) with some 45 scanlines (y).



Figure 4-27. Four cycles of Marina del Rey (Cycles 1, 5, 9 and 13).



Figure 4-27B. Zoom-in, rotated image. Thematization with the same signature yields different amount of water classes.



Figure 4-28. Portion of Frame 178 from Flight 73-036 showing residential areas around the Los Alamitos Naval Air Station.

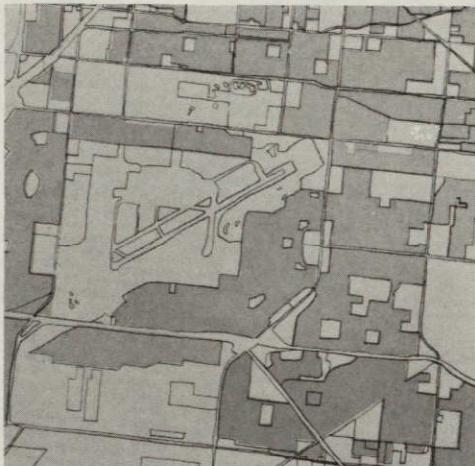


Figure 4-29. Trace of homogeneous segments of residential areas from images of previous U2 flights.

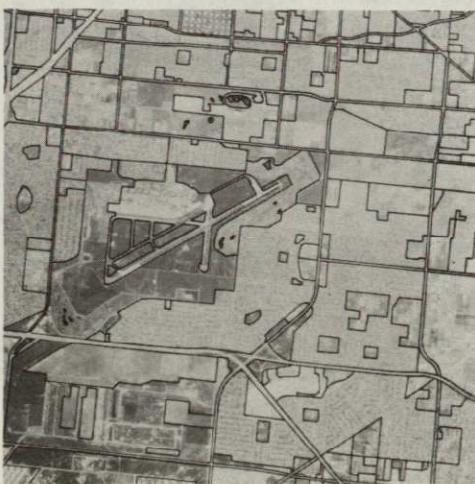


Figure 4-30. Overlay on the U2 image prepared for identification of digital ERTS data displayed on IMAGE 100.



Figure 4-31. IMAGE 100 CRT view of ERTS Scene 1234-18021 around Los Alamitos Naval Air Station, CCT input at 3 by 4 enlargement in x to y (note area 4).



Figure 4-32. Theme alarm corresponding to Training Site 4 of Figure 4-31.

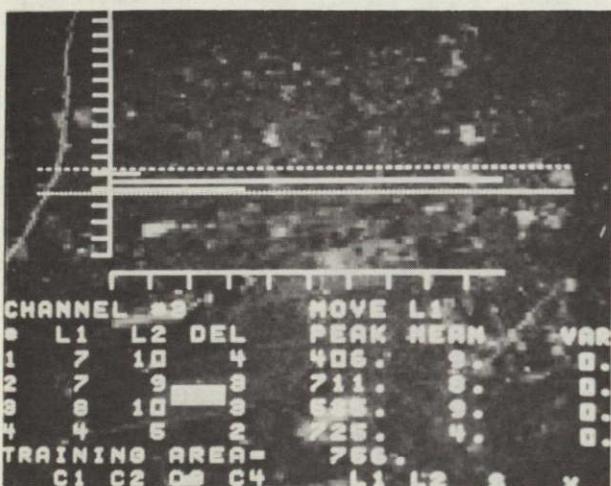


Figure 4-33. 1D Histogram display, Channel 3 for signature of Site 4 in Figure 4-31.

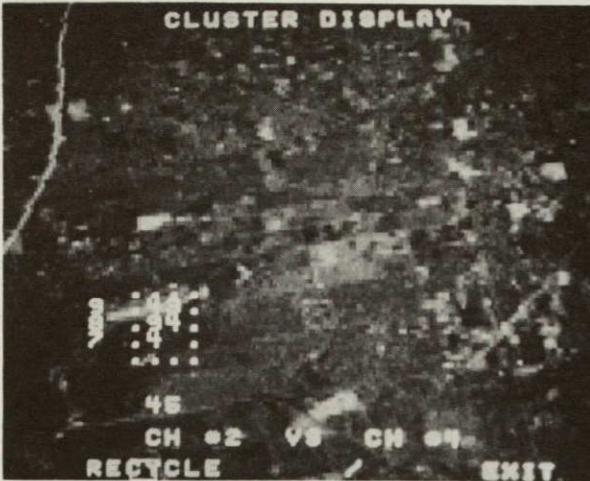


Figure 4-34. 2D cluster display, Channel 2 vs Channel 4, projected for 4D histogram.

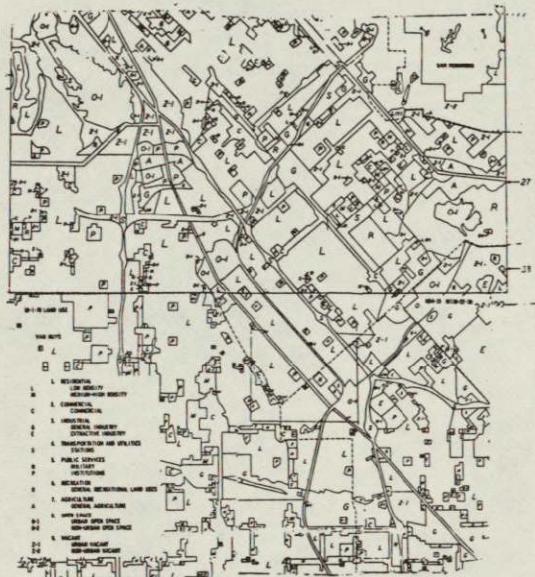


Figure 4-35. Los Angeles ground truth.

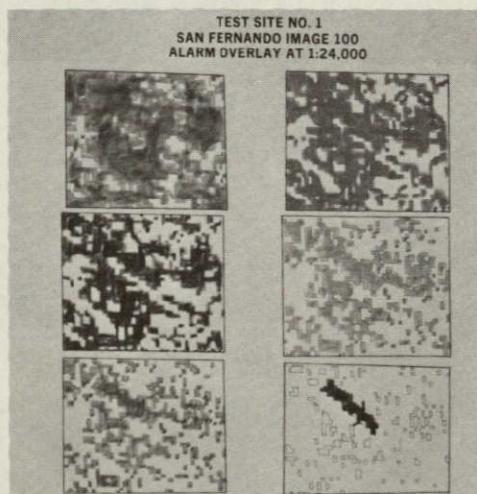


Figure 4-36. Sequential theme alarms from an IMAGE 100 overlayed on a County land use map derived from the San Fernando analyses.

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SECTION 5

AIRCRAFT UNDERFLIGHTS IN SUPPORT OF ERTS DATA USE IN COLAGE

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## SECTION 5

### AIRCRAFT UNDERFLIGHTS IN SUPPORT OF ERTS DATA USE IN COLAGE

#### 5.1 TEAM'S APPROACH TO AIRCRAFT UNDERFLIGHT DATA REQUESTS AND USES

The flow of aircraft underflight data acquisition and analysis as it pertains to the COLAGE Program, is shown in Figure 5-1. NASA aircraft support was supplied to the project from both the NASA Ames Research Center and the Johnson Space Center. Ames supplied pre-ERTS simulation data and ERTS underflight data. ERTS underflight data was also supplied by the Johnson Space Center. The primary input from Ames was film products while scanner data was additionally furnished from Johnson. The film inputs were supplied to the Los Angeles County Regional Planning Commission, the primary users. They used photography to assess the content of each scene as well as to derive ground truth. A number of other County agencies, classified as secondary users, also made use of the data. Some of these secondary users also supplied additional ground truth to the study team.

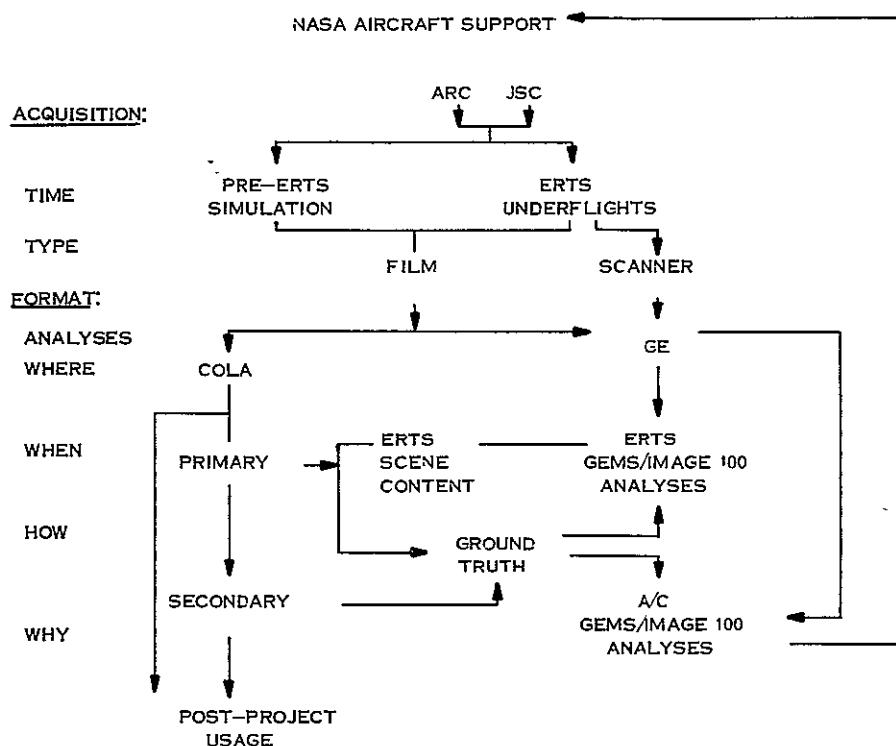


Figure 5-1. Aircraft Underflight Data Acquisition and Analysis Flow

Apart from photointerpretation, aircraft data were also machine analyzed initially with the GEMS and later with the IMAGE 100 and compared with available ground truth. These efforts were reported to the aircraft support program offices by way of the NASA technical monitors.

In addition to the use of this data in the studies described, there has been and will continue to be extensive post-project usage particularly by the County of Los Angeles and, to a lesser degree, by the members of the study team from GE.

When formulating requests for underflights, every team member was asked a preference as to date, coverage sensor/format and of the data. The County's requirements were given especially heavy emphasis in these selections.

The COLAGE project received excellent support and superior data from the NASA Aircraft Program. Outputs from every type of available sensor configuration and format, a wide variety of scales, several alternative flight line layouts were obtained. The data received was also timely. During the project the use of aircraft data was intensive. The post-project use is expected to be just as intensive and indeed the lasting value to the County is worth much more than the site cost of the experiments conducted during the 2-year effort.

## 5.2 PRE-ERTS SIMULATION DATA

### 5.2.1 NASA CALIFORNIA ECOLOGICAL TEST SITE FLIGHTS

There was a series of "Ecological Test Sites" across the U.S. that NASA and the USGS had developed of which the one in Southern California was of particular interest to the COLAGE team. NASA/Ames made several rolls of this image available to the COLAGE project. The U2 flight lines and the type of cameras used for the pre-ERTS data are listed in Table 5-1. Generally the coverage included the urban and coastal areas within Los Angeles County with some interfaces shown between adjacent counties, but most of the coverage was restricted to the heavily populated parts of the County. Hence there was a need for coverage of the total County to meet the needs of the investigators geographically and to obtain an explicit time-wise "underflight".

Table 5-1. Pre-ERTS Aircraft Flightline and Sensor Designations Over Southern California Ecological Test Site a la NASA Ames

Flight No.	Date	Sensor
71-025	9/1/71	Vinten
71-047	10/13/71	I <sup>2</sup> S
71-048	10/14/71	Vinten
71-075	12/9/71	Vinten
72-020	2/3/72	Vinten
72-035	3/3/72	Vinten

Simulation data did have the utility of orienting the team and it enabled the County investigators, in particular, to begin the selection of subtest sites of interest in advance of the formal part of the investigation. From the GE investigators' viewpoint, since the I<sup>2</sup>S data from this batch was unique, an attempt was made to use the I<sup>2</sup>S viewer at the Goddard Space Flight Center for optical compositing, etc., in a "simulation" experiment sense. At a later point in the project, an attempt was made to load the I<sup>2</sup>S data into the IMAGE 100 for machine analysis via the scanner input; namely, to load and register the four different bands as an exercise in using this mode of input. Otherwise, the pre-ERTS data was used primarily in the photointerpretation phase of the investigation, almost all of it before the contract was formally initiated.

Selection of the Southern California Test Site indeed was very appropriate on NASA's part from an ecological point of view, but it did not seem to have developed as fully as some of the other test sites designated for ecological analysis.

### 5.2.2 PHOTO MOSAIC SCENE FROM LOW-LEVEL AIRCRAFT FRAMES

A pre-ERTS mosaic of the anticipated Los Angeles "Test Site" that simulated the coverage of approximately one ERTS scene was located by the investigators through a report published by NASA-Goddard. The composite

was made from 10,000 individual scenes taken by low-level aircraft, each covering one square mile. The mosaic was processed by the Aero Service Company of Philadelphia, Pa. This mosaic was used primarily for orientation by the County team members.

Here it might be mentioned that discussions often took place at a few ERTS symposiums concerning the value of data that could be inferred from an aircraft mosaic compared with the information that could be derived from a direct satellite image of the same area. Generally, it was agreed that a mosaic is a striking representation of the site, but it does not portray the site as accurately as the images taken by sensors explicitly designed for accurate spectral representation if spatial resolution is maintained constant.

### 5.3 NASA AMES RESEARCH CENTER U2 FLIGHTS

#### 5.3.1 FLIGHT 72-215, DECEMBER 14, 1972

Data from Flight 72-215 was received at a scale of 1:130,000. This was the first County-wide infrared coverage that included Santa Catalina Island. The flight was made within hours after ERTS Scene 1144-18-0 15 of December 14, 1972 covered the same area. This simultaneous coverage of a test site by aircraft and satellite imagery was perhaps a first in the history of the ERTS program. The ERTS image received from NASA Data Processing Facility and even the non-standard ERTS scene, as enhanced by the GE Photographic Engineering Laboratory in Beltsville, Maryland, were both received before the aircraft imagery, attesting to the efficiency of the NDPF image processing capability for bulk photographic products! Table 5-2 lists the salient parameters about this flight data, while Figure 5-2 gives its flight lines map.

Table 5-2. Flight Summary for Flight No. 72-215

Sensor Type:	Vinten	Vinten	Vinten	Vinten	RC-10
Lens Focal Length:	1-3/4 in.	1-3/4 in.	1-3/4 in.	1-3/4 in.	6 in.
Film Type:	Plux X, 2402	Plus X, 2402	Infrared Aerographic, 2424	Aerochrome Infrared, 2443	Aerochrome Infrared, 2443
Spectral Band:	475-575 nm	580-680 nm	690-760 nm	510-900 nm	510-900 nm
f Stop:	13.5	13.5	9.5	9.5	8
Shutter Speed:	1/250	1/250	1/250	1/250	1/300
No. of Frames:	94	94	94	94	82
% Overlap	60	60	60	60	60
Quality	Good	Good	Good	Good	Good

#### 5.3.2 FLIGHT 73-036, MARCH 14, 1972

This flight produced imagery at a scale of 1:32,000. The resulting data was sufficiently detailed as to serve the Los Angeles Regional Planning Commission's needs. It was used as "ground truth" for various ERTS-1 substudies described earlier. In particular, the natural color mode was used by OVAAC8 planners for defining training sites, for the housing study reported in Section 4, and for evaluation of the IMAGE 100 outputs.

GE also used the imagery from Flight 73-36 in an attempt to digitize it in the color format. The true color imagery was found to be too dark for both GEMS and the IMAGE 100, while the CIR mode turned out to be thus useful for area measurements of water bodies and parks. More intensive machine analysis of this imagery was not attempted in so far as the scope of the investigation was concerned.

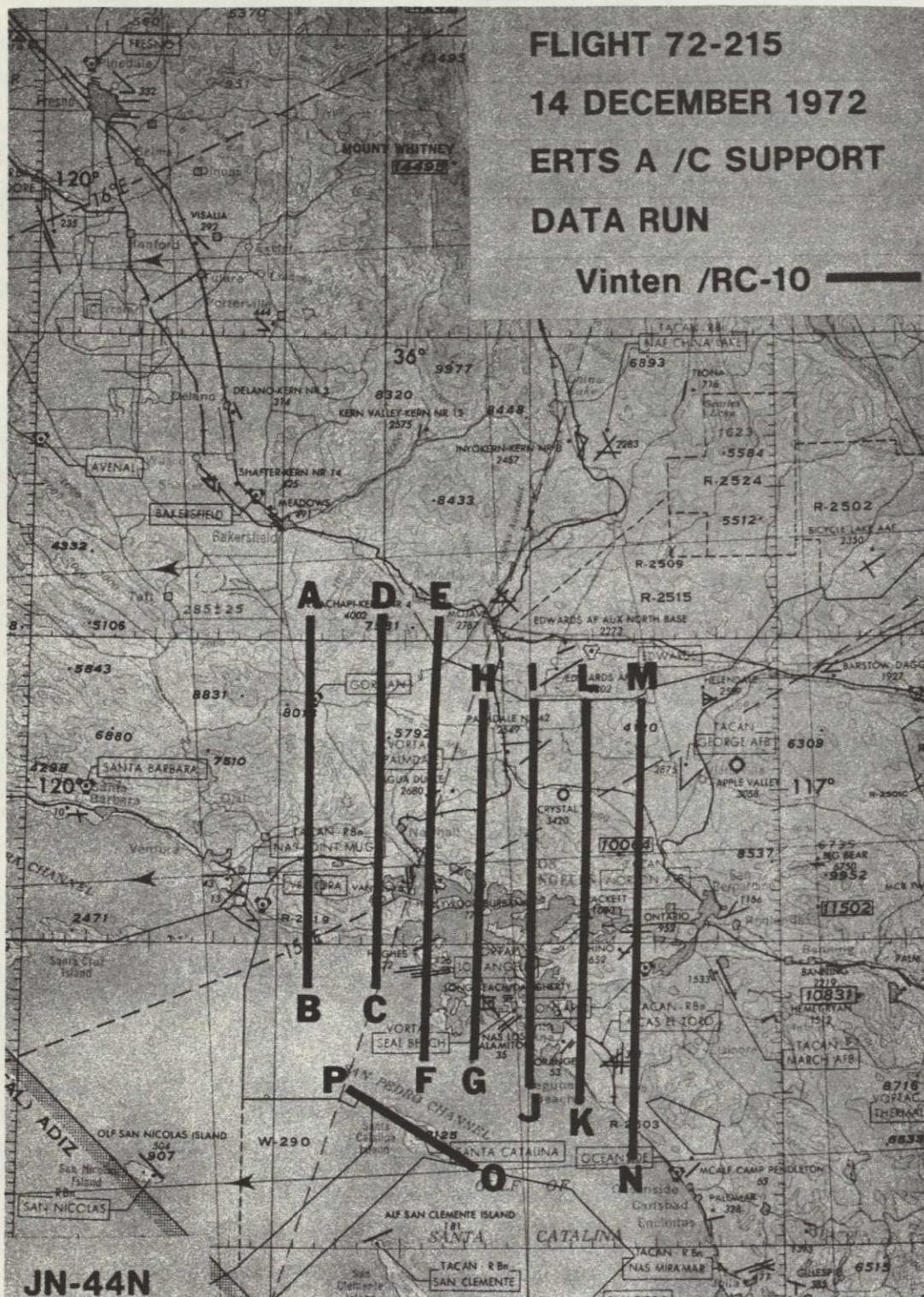


Figure 5-2. Flightline Map for Flight 72-215

For each underflight, the County of Los Angeles Regional Planning Commission staff generated an in-house Flight Map Index by a careful examination of each frame to identify the "ground control" points and mosaicing the frames downtrack as well as crosstrack. Since Underflight 73-036, also was carried out within a few hours of the ERTS-1 overpass of Scene ID 1234-18021, the Cola Flightline Index Map was overlayed at GE on the NASA ERTS image to produce the composite grided scene of Figure 5-3.

The NASA-ARC Earth Resources Aircraft Project Flight Summary Report for this underflight is enclosed as Appendix C, Part I for illustrating representative documentation for an underflight.

### 5.3.3 FLIGHT 73-108 OF JULY 2, 1973

A distinctive feature of this underflight was the first oblique imagery obtained in the project. The total test site was covered using the rocking camera feature. It provided a different perspective than the previous two flights. Generally, the use of this flight has been minimal because the ERTS data during this time had too high a cloud cover content. Table 5-3 provides a Flight Summary and Figure 5-4 a File Line Map for this flight.

Table 5-3. Flight Summary for Flight No. 73-108

Aircraft No: 4		Date: 2 July 1973	
Sensor Package: A-1 Configuration			
Sensor Type:	HC-730V	HC-730R	HR-732
Lens Focal Length:	6"	6"	24"
Film Type:	Ektachrome EF Aerographic, SO-397	Ektachrome EF Aerographic, SO-397	Aerial Color, SO-242
Spectral Band:	400-700 nm	400-700 nm	400-700 nm
f Stop:	11	11	8
Shutter Speed:	1/150	1/150	1/75
No. of Frames:	96	95	627
% Overlap	60	60	60
Quality	Excellent	Excellent	Good
Remarks	Processing residue-frs. 10-13		Sporadic traces of processing residue throughout roll

### 5.4 NASA JOHNSON SPACE CENTER FLIGHT NC130B OF NOVEMBER 2, 1973

The final COLAGE, ERTS-1 underflight was provided by NASA/JSC as Mission 254-5L4, Test Site 289. In some respects, this was the "Skylab Simulation" underflight as far as the type of sensors were concerned.

The Bendix 24-channel multispectral scanner and the IR scanner provided new types of data to COLAGE. The mission was flown at two different altitudes; one at 12,000 feet and the other at 30,000 feet. These altitudes were arrived to obtain the RC10 imagery at a scale of 1:24,000 and a reasonable resolution for the scanner.

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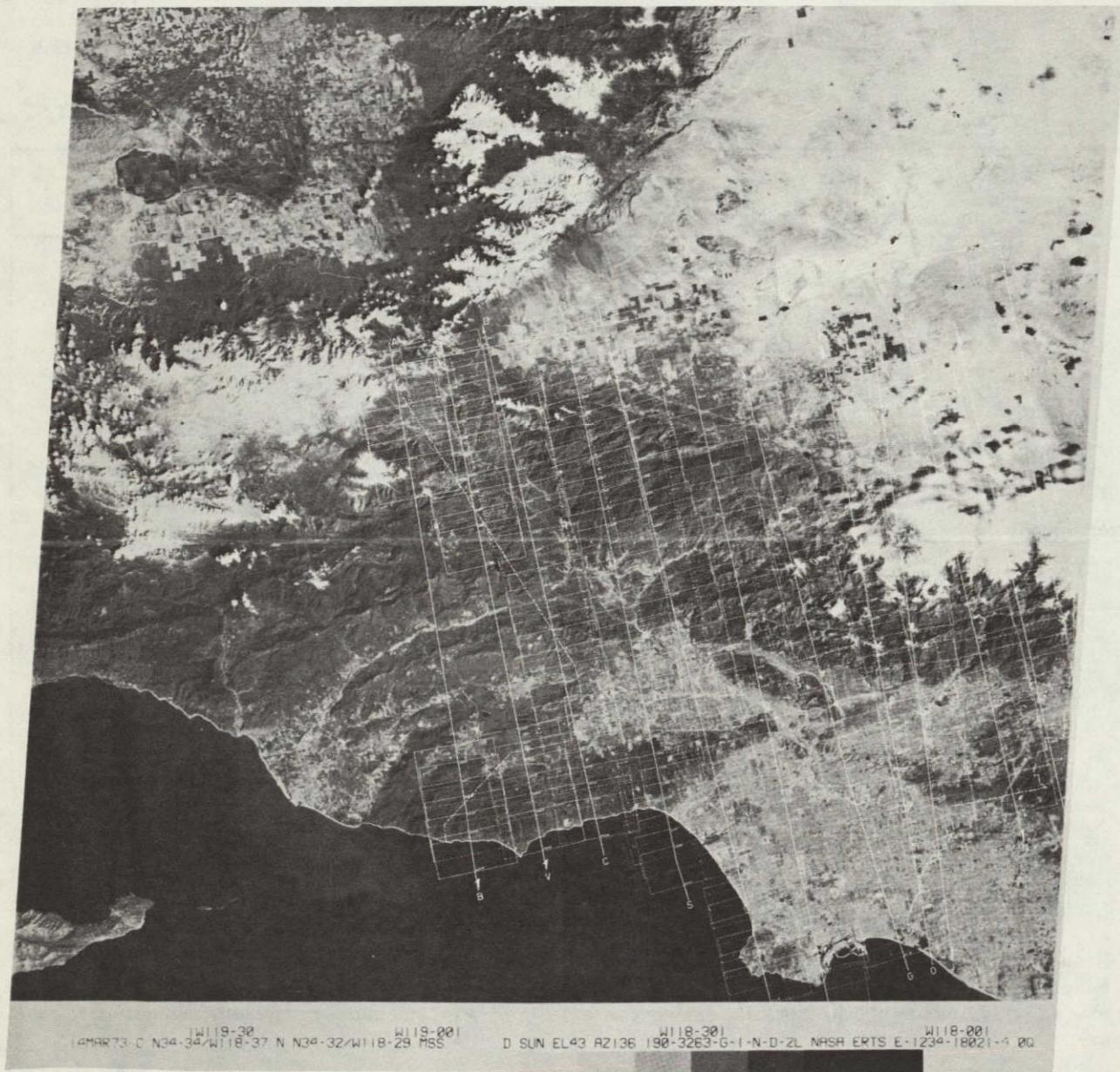
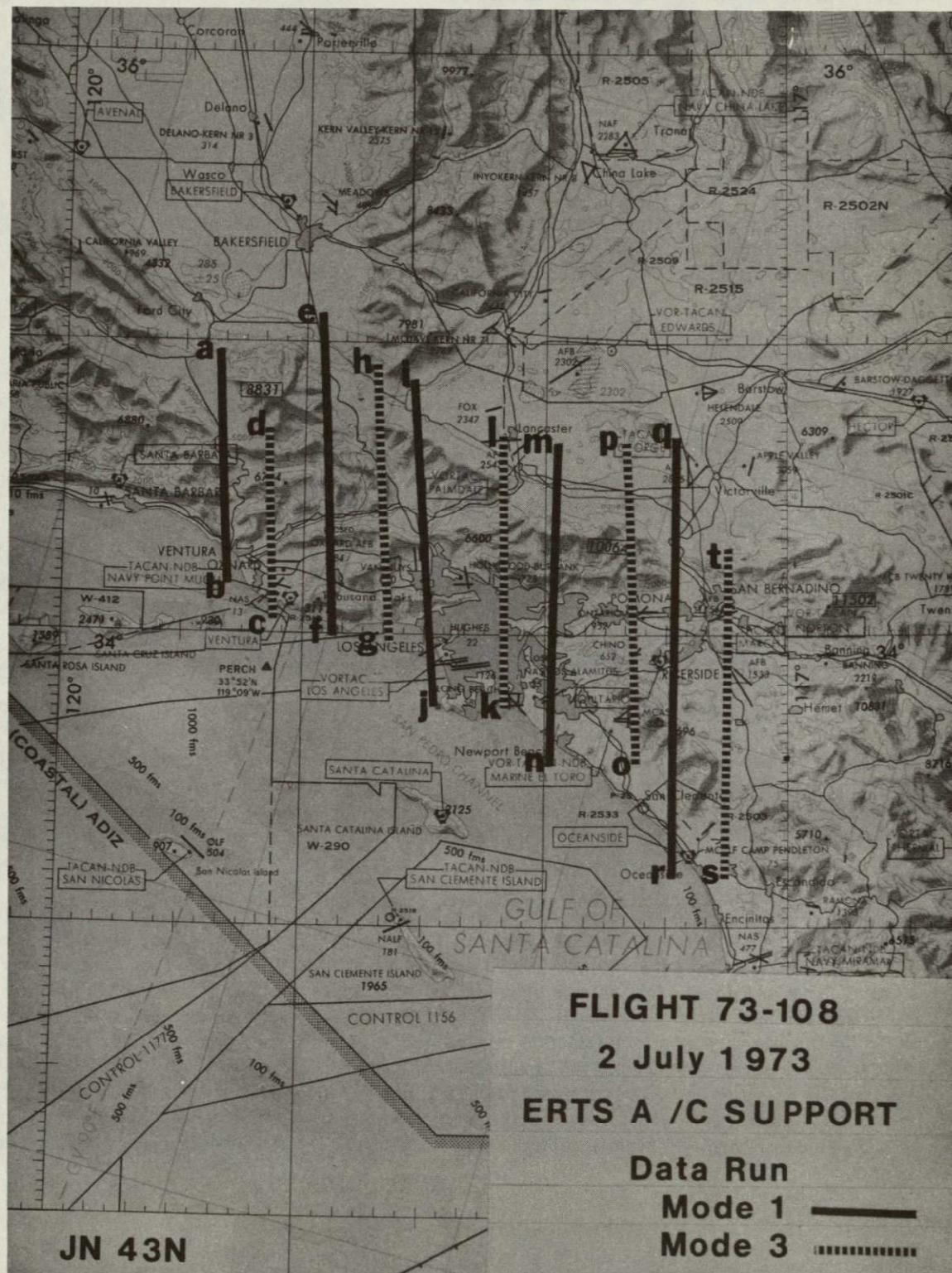


Figure 5-3. Flightlines of U2 With A3 Configuration Flown on March 14, 1973 During Which ERTS Overflew



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Figure 5-4. Flightline Map for Flight 73-108

The principal use of this data was for machine analysis in contrast with photointerpretation of previous flight data. Earlier, the Bendix scanner data was reformatted for input to the IMAGE 100 as a pseudo-ERTS tape format, analyzing only four bands at a time. Subsequently, software to analyze up to 16 bands simultaneously has been developed and this multi-band analysis is still under way.

Excerpts from the JSC Earth Observations Aircraft Program Project Support Plan for this flight are included in Appendix C, Part II.

#### 5.5 "COLAGE-FLOWN" LIGHT AIRCRAFT UNDERFLIGHT - MAY 7, 1973

An experimental underflight was conducted on May 7, 1973 piloted by a member of the COLAGE team from GE (now with OVAAC8). Other co-investigators from the County and GE onboard the flight used hand-held cameras to take images of the Los Angeles County area.

A pilot checkout flight on May 5th immediately followed the Mid-Project Conference in Los Angeles, and this was followed on May 6th by a ground truth expedition.

The two-day flights covered most of the project sub-study sites off the Santa Monica Bay, over the Santa Monica Mountains, the San Fernando Valley, the Antelope Valley, the San Gabriel Valley and the Los Angeles urban core. The Los Angeles and Long Beach downtowns were somewhat less sunny than the other areas, as the ERTS scene for that time shows (Figure 3-13). Flight altitudes ranged between 3000 and 9000 feet. The 35mm cameras carried regular speed Ektachrome and Kodachrome films.

The county planners offered much useful in-flight commentary and provided notes on the post-flight slides. Some of these views have been reproduced in a number of places in this report. The color slides give the reader/viewer a better 'feel' for the 'ground truth' as well as enabling him to appreciate (as the team members did more so since the underflight) the enhanced value of synopticity and the precession of NASA's underflight as well as ERTS coverage and data.

#### 5.6 CONCLUDING REMARKS ON COLAGE UNDERFLIGHTS DATA ANALYSIS

The coverage of the aircraft underflight data received was so comprehensive and the quality so superb that the scope as well as resources of this investigation could not do justice to either of them. Thus, in spite of both the extensive non-project but operational use of the aircraft data at the county and the preliminary attempts at digitizing the film products at GE, very little quantitative measures of the data characteristics could be determined within the above constraints. Hence, the summary for sensors and products available from NASA/Ames, used in COLAGE as shown in Table 5-4 would be of wider interest.

While the COLAGE Flight 73-036 was the first operational one for the A3 configuration, already a sensor package called configuration B3 with a 32-inch focal length lens and twin 9 inch x 18 inch frames coverage of 3 x 6 nm ground area, at scale 1:24,000 has been added to the Ames Aircraft Project capabilities. It is thus possible to acquire data simultaneously from a B3 and RC-10 packages to meet the two basic scale requirements of the county planners (via 1:24,000 and 1:127,720 respectively) for detailed area studies and regional policy presentations. Previously the county has been extracting information at 1:24,000 scale and telescoping it into the so-called USGS Quad Mosaic at the 1 inch = 2 mile scale. With the availability for the first time of RC-10 data at the almost appropriate scale, the county planners have been able to update the regional Quad Mosaic directly. Significance of this situation to regional planners elsewhere needs to be developed further.

Table 5-4. NASA/Ames Research Center Earth Resources Aircraft Project (ERAP) Characteristics  
of Sensors (November 1972) Used in COLAGE Underflights

COLAGE Flight No.	Sensor Package	Sensor Name	Lens Focal Length (in.)	Frame Format (inches)	Ground Area Covered (per frame) @65,000 MSL (Nominal)		Nominal Ground Resolution @65,000 MSL (feet)	Remarks
					(nm)	Scale		
Pre-COLAGE	I <sup>2</sup> S Multispectral Camera	I <sup>2</sup> S Mark I Camera	100 mm	3.5 x 3.5 (4 images)	9 x 9	1:184,000	20 - 30	(Color IR film) 4 Spectral Bands 400-470 nm, 470-590 nm, 590-690 nm, 740-900 nm
72-215 Dec '75	Vinten System A/B	Vinten	1-3/4	2-1/4 x 2-3/16	14 x 14	1:454,000	30 - 50	Normal filter comb. = 475-575 nm
		Vinten	1-3/4	2-1/4 x 2-3/16	14 x 14	1:454,000	30 - 50	Normal filter comb. = 580-680 nm
		Vinten	1-3/4	2-1/4 x 2-3/16	14 x 14	1:454,000	30 - 50	Normal filter comb. = 690-760 nm
		Vinten	1-3/4	2-1/4 x 2-3/16	14 x 14	1:454,000	30 - 50	Normal filter comb. = 510-900 nm
	Wild RC-10 Camera	RC-10	6"	9 x 9	16 x 16	1:128,000	20 - 25	
73-108 July '73	A-1 Configuration	HC-730V	6"	9 x 9	16 x 16	1:128,000	20 - 25	Vertical
		HC-730L	6"	9 x 9	---	---	---	Left Oblique
		HC-730R	6"	9 x 9	---	---	---	Right Oblique
		HR-732	24"	9 x 18	4 x 8	1:32,000	2 - 8	Data applies to vertical mode - can also be operated in rocker mode
73-036 May '73	A-3 Configuration	HR-732F	24"	9 x 18	4 x 8	1:32,000	2 - 8	Forward camera
		HR-732C	24"	9 x 18	4 x 8	1:32,000	2 - 8	Center camera
		HR-732R	24"	9 x 18	4 x 8	1:32,000	2 - 8	Rear Camera

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COLAGE TEST SITE COORDINATION

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## SECTION 6

### COLAGE TEST SITE COORDINATION

#### 6.1 ERTS TEST SITES AND TEST SITE COORDINATION

NASA regards the role of test site coordination as a key among the ERTS user investigations as evidenced by their specific references to this function. The activity of a test site coordinator vary from test site to test site depending on such factors as the geography of the site, subject and scope of the investigation, relative locations of the team members, primary and secondary users, etc.

The COLAGE test site boundaries were arrived at as a result of a team consensus involving Los Angeles Regional Planning Commission representatives and the General Electric investigators. The site, as defined, centered around Los Angeles County. Both the data and user interfaces were initially expected to be local, but results were found to be of interest across the State of California among a class of secondary users.

Primary site coordination in the project was carried out by Mr. Jene McKnight of the Regional Planning Commission. He generally arranged for acquisition of reference data/ground truth and usually communicated the team's findings to the secondary users in the Southern California area.

#### 6.2 ACQUIRING GROUND TRUTH

##### 6.2.1 REFERENCE DATA FOR LAND USE ANALYSIS

Initially, reference data was acquired through the Los Angeles County Planning Commission which supplied land use, soils, geologic, topographic, vegetation and other types of maps. These maps had significant limitations. Most were based on data acquired during or prior to 1971 and they were not current for purposes of comparison with ERTS imagery of the same area which was only weeks or months old. In addition many of these maps were prepared to special scales which did not match the scale of ERTS imagery. Further, the maps were derived from data that was mono-spectral and non-temporal. Hence, in the project aircraft data was subjected to intensive photointerpretation, so that it served as pseudo ground truth. When such air coverage was found to be lacking, the needed information was obtained by on-site visits as required throughout the course of the investigations.

##### 6.2.2 REFERENCE DATA FOR OTHER ANALYSES

Ground truth or reference data should be preplanned to permit full interactive evaluation of and post-analysis assessment. A quick search for available ground truth during the experiment usually produces inadequate results compared with preplanned acquisition. For example, if any of the agricultural substudies that were conducted during the COLAGE investigation had involved identification of plant species rather than the pattern analysis, a much closer and timely interface would have been required with the County Agricultural Department before meaningful results could have been expected. Another example would be the surface water area measurement. The area data provided by the State Water Resources Board and the City of Los Angeles Water and Power Department were adequate for the machine analysis as carried out but this data was inadequate to corroborate sedimentation patterns that appeared to emerge for which water quality data was required. In addition to the agencies contacted, the kind of ground truth needed to improve or fully exploit the results was of such a specialized nature that it would have required a concentrated and expensive effort to compile the intensive information in time for use during the analysis by many other agencies.

Yet another case: ground truth on parks in the area was available from site maps supplied by the County Recreation and Parks Department, but analysis of the machine-produced structural pattern pixel-wise would have required a concentrated and costly effort on the part of the County Recreation and Parks Commission in advance of the study. This type of information was therefore extracted from aircraft data which was of adequate resolution and frequency.

Another major source of requisite ground truth was the Field trips conducted by the County co-investigators as necessary to ascertain specific findings. Examples of these included verification of land cover that differed from the information shown on the land use maps, checking out newly identified grading sites, agricultural status in the Antelope Valley, and an on-site geological investigation of the Sheep Creek Fan, etc.

### **6.3 SECONDARY USER INTERFACES**

Secondary users included individuals or groups who represented an organization with interests in earth observational data of the COLAGE test site. These users had either seen and discussed the imagery and analyses or with whom correlative discussions had been held during the project.

Time spent by County personnel in contacts with the secondary users would add up to hundreds of man-hours, so lively was their interest. County personnel contacted many of these secondary users early in the investigation when they were searching for ground truth. Later many of these users contacted the County coordinator for the latest information to date, and these contacts are still being maintained by the County in many cases. The interests of these secondary users was varied and wide ranging. The specific contacts and contents were fully described in the monthly progress reports by the County Regional Planning Commission which were appended to the bimonthly reports by GE to NASA.

A summary of the types of secondary users is presented in the following paragraphs.

#### **6.3.1 PUBLIC AGENCIES**

1. Los Angeles County Departments. These included other departments of the County of Los Angeles primarily concerned with physical data within the County (as listed in Table 6-1). In addition, agencies dealing with social data (such as the Department of Urban Affairs) often had pertinent ground truth as well as interest in analysis results.
2. Planning Departments in Local Government within or adjacent to the County boundaries, such as the Cities of Los Angeles and Long Beach. While individuals in these groups explored the utility of ERTS data and participated in some evaluation, their major interests were in aircraft under-flight data.
3. Planning Departments from Adjoining Counties including member counties of the Southern California Association of Governments (SCAG). This group is a regional organization comprising representatives from: Los Angeles, Ventura, Imperial, Riverside, San Bernardino and Orange Counties. A number of presentations were made to SCAG, and their personnel attended briefings and meetings conducted by COLAGE. In view of their large area orientation, it was felt that ERTS data would provide a new and primary source to supplement the secondary data they usually had to deal with. But for SCAG to benefit fully from ERTS information, a well-thought out project would have to be developed around their specific requirements. (Such an attempt was made in the follow-up proposal).
4. State of California Departments including the Department of Water Resources.
5. Federal Agencies that included personnel from the U.S. Department of Agriculture, the Department of Housing and Urban Affairs of Los Angeles.

#### **6.3.2 PRIVATE INSTITUTIONS**

1. Private Utilities planning consultants, map makers and engineers from aerospace companies in the Southern California region.

2. Academic Personnel from around the test site, both NASA-funded ERTS investigators and independent researchers, investigators from the University of California at Riverside, and others with specific interests in the COLAGE project from the University of California at Los Angeles.
3. Professional Societies of local or statewide planners geographers, and other types of earth scientists.

Table 6-1. LA County Departments Interfaced as COLAGE Secondary Users

Agricultural Commissioner	Flood Control District
Air Pollution Control District	Forester and Fire Warden/Fire Protection Districts
Arboreta and Botanic Gardens	Health Services
Assessor	Museum of Natural History
Board of Supervisors	Parks and Recreation
County Engineer	Roads
Data Processing	Sheriff
Facilities	Small Craft Harbors
Farm Advisor	Urban Affairs

#### 6.4 PROJECT PRESENTATIONS AND ORGANIZATION OF SOUTHERN CALIFORNIA ERTS CONFERENCE

Substantial effort went into preparations by project personnel to interested individuals and groups not only in Los Angeles, but throughout the County and the State. Papers at certain national symposia and seminars during international visits reached an even wider audience.

Every visit that GE personnel made to Los Angeles in connection with COLAGE included not only working sessions with members of the Regional Planning Commission staff, but also project briefings to secondary users. The project kickoff meeting in August of 1972 included a session with the County co-investigators and an explanation of the ERTS system. Other secondary users were briefed on these topics in a second session, and they were asked for ground truth inputs at that time. A number of such contacts were made during the course of the project.

The mid-project review (held at Los Angeles on May 4, 1973, Appendix D) was followed by a presentation to others interested in the results of the COLAGE investigations.

This brief review of COLAGE Test Site Coordination should give an idea of the nature and the extent of the effort made by the team to ascertain and enhance the utility of ERTS data generally and COLAGE outputs specifically.

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SECTION 7

UTILITY OF ERTS-1 AND OTHER REMOTELY SENSED DATA  
FOR URBAN AND REGIONAL PLANNING

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## SECTION 7

### UTILITY OF ERTS-1 AND OTHER REMOTELY SENSED DATA FOR URBAN AND REGIONAL PLANNING

#### 7.1 INTRODUCTION

While this report has frequently identified the usefulness of results in connection with various substudies described in Sections 5 and 6, it is now necessary to summarize the overall utility of ERTS and underflight data, and other remotely sensed information for urban and regional planning activities. This summary will consider not only its usefulness for planning activities of Los Angeles County, but also from its possible influence on planning in general. One of the objectives of this project was consideration of the usefulness of remotely sensed data to the larger planning community. This was the primary interest of OVAAC8 consultants. The approach to determining utility will involve identification of the principal determinants of ERTS-1 data utility, which will then be followed by an estimate of the utility of ERTS-1 data for general urban and regional planning.

A good deal of the reporting during this project was directed toward the aerospace community which interfaces with regional planning interests. At the ERTS symposiums sponsored by NASA, participants were asked to enumerate the significant findings and applications of remotely sensed information and estimate its dollar values.

Utility of remotely sensed data will be directed in this report to the planning community at large, and while no values will be set on any of the results, its value in planning for urban areas will be stressed.

The COLAGE project has involved the interaction of urban planners and those engaged in remote sensing. The remote sensing groups are associated with aerospace organizations. They are high level technologists often belonging to large scale organizations. They are well trained but are engaged in the solution of relatively simple problems. Planners, on the other hand, are usually associated with small scale organizations, are less highly trained than the remote sensing and aerospace groups, but they are attempting to solve very complex problems associated with management of urban affairs. These respective orientations affect the perceptions the two groups have of the utility of remotely sensed data to urban and regional planning. Both the planning brotherhood and the remote sensing fraternity tend to mis-estimate the usefulness of remote sensing in planning. The remote sensing fraternity tends to overestimate its usefulness while the planners are prone to underestimate its potential.

#### 7.2 PRINCIPAL DETERMINANTS OF DATA UTILITY IN PLANNING

In order to gauge the usefulness of ERTS products for urban and regional planning, it is necessary to take into account the general nature of urban and regional planning. Of utmost importance is the fact that planning is political in nature in the sense that it must deal with the values of many groups of people within the area where planning is conducted. This means that information about peoples' values is of foremost importance. ERTS data has no utility for identifying these value orientations.

Planning is also predictive in the sense that it must identify alternative futures and evaluate these in terms of goals which are based on values. ERTS reflects current conditions and is of limited value for predicting long term future conditions.

Planning is multi-disciplinary and open-ended. This was evidenced by the varied interests of the panel members who attended the ERTS symposiums. There were exact scientists, natural scientists, and social scientists who brought specialized training and experience in various phases of planning. This signifies that data from a vast range of sources is necessary. ERTS will be one of a wide variety of planning data sources. It will generally supplement, not replace, other planning data sources.

Planning is often carried on by large numbers of small scale organizations which operate with small budgets and lack specialized personnel. This suggests that ERTS data will have to be made inexpensive and simple to manipulate if it is to be useful to these groups.

Finally, urban planning is currently something of an "urban housekeeping" function oriented primarily to tidying up urban areas. Consequently, planning is oriented to the internal problems of cities and has tended to neglect the external relationships (city-hinterland relationships). The "urban housekeeping" orientation works to the disadvantage of ERTS with its small scale and coarse resolution.

#### 7.2.1 SCOPE OF URBAN AND REGIONAL PLANNING

Consideration of the broad general concerns of urban and regional planning helps to define the utility of ERTS. The general concerns of planning are:

1. Physical
  - a. The man-made or built environment
  - b. The natural environment
2. Economic
3. Social
4. Political (value-oriented); and
5. Fiscal.

ERTS products are most useful for supplying information about the physical components, especially the natural component of the physical environment. They appear to have little or no utility for dealing with the economic, social, political and fiscal concerns of planning which, as a group, are probably becoming relatively more important than the physical factors.

Consideration of the subject matter of urban planning contributes to a more explicit definition of ERTS utility. The subject matter of planning, defined in terms of the topics addressed, may include:

1. Land Use
2. Housing
3. Transportation
4. Open Space and Recreation
5. Resource Conservation and Management
6. Seismic Safety
7. Public Safety
8. Noise
9. Scenic Highways
10. Environmental Quality
11. Public Services and Facilities
12. Water and Waste Management
13. Urban or Community Design
14. Historic Preservation
15. Community Development
16. Urban Redevelopment
17. Human Resources Development
18. Air Quality

19. Economic Development
20. Energy Conservation; and
21. Other Optional Factors.

ERTS products would appear to have some limited utility in many of these areas. However, they have the greatest utility in the areas of resource conservation and management. Next in order, in terms of utility, is urban design and general environmental quality assessment. There is some limited potential for providing highly generalized land use information for urban and regional scale planning. ERTS products appear to have little or no utility for topics such as human resources or urban noise prevention planning.

In planning for each of the subject matter areas listed above it is necessary to:

1. Identify needs, problems, issues, opportunities and assets
2. Formulate goals and objectives
3. Develop and evaluate policies; and
4. Establish action programs and projects.

ERTS greatest utility is in the first of these areas. It is of little or no use in establishing goals, policies and action programs.

The scales at which planning is carried out are a major determinant of ERTS utility. Planning is carried out at the following general scales.

• Site	1:50 to 1:1,200*
• Neighborhood or Community	1:1,200 to 1:6,000*
• Area or Subregional	1:6,000 to 1:24,000*
• Regional or Metropolitan	1:24,000 to 1:125,000*
• Large State or Major Sub-National Area	1:125,000 to 1:500,000*
• National or Greater	1:500,000 - and above*

Most urban and regional planning activities are carried on at the site, community, area and regional scales. Indeed, the greatest volume of activities is concentrated at the site and community scales where ERTS outputs have little or no practical utility. ERTS outputs are of marginal usefulness at the regional or metropolitan scale. The greatest utility will be at scales greater than 1:125,000.

The temporal orientations of planning are significant for defining the planning utility of ERTS products. The temporal orientations of planning are:

1. Current (immediate)
2. Short range (up to 5 years in the future)
3. Medium range (up to 10 years in the future); and
4. Long range (greater than 10 years, usually 20-25 years in the future).

ERTS products are most useful for current concerns and of limited or no usefulness for defining or predicting medium and long range futures.

\* Subjectively estimated range of scales

### 7.2.2 PLANNING PROCESS

The process of planning is another determinant of ERTS-1 utility. The process of planning involves the following steps:

1. Plan making and adoption
  - a. Problem identification
    - (1) Research
    - (2) Public interaction and consultation
  - b. Goal setting (perhaps the key act in planning)
  - c. Policy formulation
    - (1) Identification of policy alternatives
    - (2) Evaluation of policy alternatives and selection of a preferred policy
  - d. Program development
    - (1) Inventory and evaluation of existing programs
    - (2) Formulation of new program proposals
    - (3) Establishment of agency roles
    - (4) Identification of constraints and evaluation of plan feasibility
  - e. Plan adoption
2. Plan implementation
  - a. Code administration and enforcement
  - b. Plan review and revision
  - c. Monitoring
  - d. Interagency and interjurisdictional coordination
  - e. Budgeting (annual and capital)
  - f. Program and project management.

ERTS products appear to have the greatest utility for the research phase of problem identification. They are also useful as communication aids in the public consultation phase of problem identification. They also have utility for monitoring purposes in plan implementation, and may have some utility for evaluation of alternative policies. Utility for other phases of the urban and regional planning process appears to be very limited.

### 7.2.3 PLANNING DATA: MAJOR SOURCES AND SELECTED NEEDS

There are two primary sources from which planning data might originate. The first is from research, and the second from communication and interaction with the general public and other governmental agencies.

Research may presently be the least important data source supplying perhaps less than half of planning data needs. Remote sensing alone can supply only a very limited fraction of research originated data. ERTS-1 products can supply only a small fraction of remotely sensed data.

Community interaction supplies the primary data for decision making in planning. Research may be growing in importance but this is offset by more and more emphasis on citizen participation as a factor in planning/decision-making.

#### 7.2.3.1 Selected Land Use Planning Data And Information Needs

Table 7-1 lists selected information and data needed for urban and regional land use planning which is only one of the many subject areas of planning. Inspection of this list will suggest that remote sensing can contribute information for perhaps 1/3 of the items listed including existing land use, improvements on the land, land suitability, form and arrangement of development, character of the housing stock, condition of development, and traffic flows and volumes. ERTS-1 products can make some limited contribution (depending on the scale at which the planning operation is conducted) of information about existing land use, land suitability, form and arrangement of development and condition of development. It should be noted that both ERTS-1 and remote sensing in general are unable to contribute significantly to the majority of the items listed.

Table 7-1. Data Needed For Land Use Planning

<ul style="list-style-type: none"><li>1. Existing land use and land use intensity</li><li>2. Existing zoning and other land use regulations</li><li>3. Current official land use plans</li><li>4. Improvements and structures on the land</li><li>5. Land values and tax rates</li><li>6. Land tenure</li><li>7. Land suitability<ul style="list-style-type: none"><li>- Slope, soil conditions, geology, flood threats, accessibility, etc.</li></ul></li><li>8. Form and arrangement of development</li><li>9. Character of the housing stock<ul style="list-style-type: none"><li>- Number, type, age, condition</li></ul></li><li>10. Condition of development</li><li>11. Traffic flows and volumes</li><li>12. Current population<ul style="list-style-type: none"><li>- Distribution (day and night); density; racial and ethnic character; age structure; occupational classes</li></ul></li><li>13. Economic base</li><li>14. Existing employment and unemployment<ul style="list-style-type: none"><li>- Number, distribution, industrial subclass</li></ul></li><li>15. Demand and need for land</li><li>16. Existing standards and criteria</li><li>17. Interest groups (actors in the planning process)</li><li>18. Private plans, proposals and hopes</li><li>19. Peoples' values and wishes</li><li>20. Problems, issues, assets, opportunities and constraints</li><li>21. Establish goals and policies</li><li>22. Existing and proposed programs and projects</li></ul>
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### **7.3 SUMMARY OF GENERAL UTILITY OF ERTS DATA FOR URBAN AND REGIONAL PLANNING**

Table 7-2 summarizes the usefulness of ERTS -1 products for supplying data for urban and regional planning.

Table 7-2. Utility Of ERTS-1 Data

<ul style="list-style-type: none"><li>1. General Concerns<ul style="list-style-type: none"><li>a. Primary usefulness - Physical - investigate natural environment and man made physical development</li><li>b. Secondary or marginal - for social, economic, political and fiscal concerns</li></ul></li><li>2. Subject Matter<ul style="list-style-type: none"><li>a. Primary utility<ul style="list-style-type: none"><li>(1) Conservation (of Natural Resources)</li><li>(2) Environmental Quality</li><li>(3) Design</li><li>(4) Water and Waste Management</li></ul></li><li>b. Secondary or marginal utility - (all other elements)</li></ul></li><li>3. Element Content<ul style="list-style-type: none"><li>a. Primary utility - Identification and appraisal of problems, issues, opportunities and assets</li><li>b. Minimal utility - Establishment of goals, policies, programs and projects</li></ul></li><li>4. Scale<ul style="list-style-type: none"><li>a. Primary usefulness<ul style="list-style-type: none"><li>(1) Large state and subnational</li><li>(2) National and continental</li></ul></li><li>b. Marginal usefulness - regional and metropolitan</li><li>c. Very limited usefulness<ul style="list-style-type: none"><li>(1) Area (Subregional)</li><li>(2) Community</li><li>(3) Site</li></ul></li></ul></li><li>5. Temporal Dimensions<ul style="list-style-type: none"><li>a. Primary usefulness - current and immediate, and short range future</li><li>b. Secondary or marginal usefulness - medium and long range futures</li></ul></li><li>6. Process<ul style="list-style-type: none"><li>a. Primary usefulness<ul style="list-style-type: none"><li>(1) Research</li><li>(2) Public interaction and consultation</li><li>(3) Monitoring</li></ul></li><li>b. Secondary or marginal usefulness - all other process steps</li></ul></li></ul>
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#### 7.4 EXAMPLES OF UTILIZATION OF REMOTE SENSING FROM COLAGE

Table 7-3 summarizes the ways in which remotely sensed information obtained as a result of the COLAGE project was used. The information was used in 4 major ways: orientation, illustration, data supply and monitoring.

Table 7-3. Examples of Use of Remotely Sensed (ERTS-1 and U2) Data Obtained by the County of Los Angeles

1. Orientation
a. County Planning Commission use of ERTS-1 imagery for zoning administration. (Presentation of zoning cases.)
b. City of Long Beach - Use aircraft imagery to present coastal cases to Regional Coastal Commission.
c. City of Los Angeles Planning Department - use of aircraft imagery for public information display
d. Southern California Association of Governments - Coastal Planning use of aircraft data
e. County Fire Department - Use of aircraft data for personnel training.
2. Illustration
a. Los Angeles County Regional Planning Commission - General plan cover (ERTS)
b. Los Angeles County Agricultural Commissioner - Illustrate annual report (ERTS)
3. Data Supply
a. Los Angeles County Regional Planning Commission
(1) Use of aircraft data to map vegetation cover in Palos Verdes Peninsula for Conservation Element of General Plan
(2) Use of aircraft data to help delineate watershed areas - Conservation Element of General Plan
b. Los Angeles County Engineer - Geological research (ERTS and aircraft data)
c. City of Los Angeles Engineer - Geologic research (aircraft data)
4. Monitoring - City of Culver City - Condition of street trees (aircraft data)

#### 7.5 THE UTILITY OF ERTS-1 PRODUCTS FOR URBAN AND REGIONAL PLANNING

ERTS-1 products are useful in urban and regional planning for:

1. Orientation (public presentations)
2. Illustration
3. Data Supply
4. Monitoring; and
5. Base maps.

NASA has emphasized the data supply capability of ERTS-1 products. Initial uses by planners tended to be for orientation and illustration, and as base maps.

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SECTION 8

RETROSPECT AND CONCLUSIONS, RECOMMENDATIONS AND PROSPECTS

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## SECTION 8

### RETROSPECT AND CONCLUSIONS, RECOMMENDATIONS AND PROSPECTS

In this section, it is appropriate to briefly review the investigators' broad assessment of their study objectives, summarize the team's specific conclusions and recommendations, and generically characterize the nature of 'follow-on' activities pertinent to the experimenters partly arising out of this joint effort.

#### 8.1 RETROSPECTIVE OBSERVATIONS ON INVESTIGATION OBJECTIVES

The investigation objectives were stated in Section 1, *in toto* from the study proposal. Recapitulating them individually:

- (1) To validate the ERTS-1 imagery by correlation with the Los Angeles County ground truth.

The nature and level of validation of ERTS-1 products was a function of the analysis tools and the character of ground truth at the team's disposal. Only bulk or system-corrected MSS data was studied.

The NDPF-supplied film products have sufficient geometric corrections for direct base data usage for the County utility listed in Section 7. ERTS standard transparencies overlayed well on the 1:1, 000, 000 Operational Navigational Charts, e.g., while the Test Site and the State of California mosaics of Section 3 were prepared at the GE photolab. In the preparation of the COLAGE underflights frame index maps of Section 5 at the County, a more detailed feature-by-feature geometric comparison of aircraft and ERTS data was made. The full-fledged cartographic assessment of ERTS MSS Film Products has been reported by a number of investigators in the literature and noted by the COLAGE team members.

Registration of the individual bands for color-compositing, using the NDPF-imprinted tick marks, is done exactly at NDPF as well as elsewhere, including by the GE Photolab, e.g., for the non-standard false-color prints described in Section 3. Registration of segments of ERTS frames over the overlap regions within successive, north-south frame-pairs of an orbital pass, has not been possible to attempt since this would require the development of special techniques and/or hardware and was beyond the scope of 'validation' set forth for this investigation.

'Validation' of ERTS data on the NDPF-supplied computer compatible tapes has involved much more effort and in fact is being continued by the investigators beyond this project. Paranthetically, it might be mentioned that the ERTS Data User's Handbook documentation on the film products is much more complete and comprehensive in contrast with that on the computer compatible tape format of the data (in particular, a thorough discussion of the steps followed in converting the sensor telemetered data to computer compatible tape format, with system or scene correction constraints on the outputs). Moreover, following-through on the implications of these constraints on the data utility/classification would be possible with actual data on hand in contrast to the prelaunch preparation of the ERTS Data User's Handbook.

In using the ERTS CCT's, primarily on the IMAGE 100, the COLAGE team philosophy has been to maintain and utilize the full fidelity of the data. Thus, with respect to the data. Thus, with respect to the pixel-wise overlap of some 40% along the scanline in the MSS CCT data, the geometrical cross-track (x) to downtrack (y) aspect ratio 'correction' was made using one of two alternate procedures: either by an artifact of filling scanlines (in the Daytona Beach phase) or by TV display adjustment alone while reading in full resolution data pixels per scanline (as in the Beltsville procedure). See Section 4.

In the experiment where ERTS CCT data registration with U2 film digitization via scanner input, the artifact of repeating ERTS pixels cross-track and scanlines downtrack to match overall field-of-view-wise was resorted to (Section 4) few pixel results for the Bouquet Reservoir and Wilshire Country Club.

Cross-scene-wide, a preliminary observation that the MSS CCT overlap regions from successive north-south frames from an orbital pass do not register pixel-by-pixel scanline-perscanline, at least radiometrically in band 5 in contrast with band 7, is being followed-up in a more systematic fashion.

Finally, the 'validation' of the rationale for oversampling in the ERTS MSS data acquisition process itself and the related implication of higher resolution along scan has not been made within the context of the COLAGE investigation.

- (2) To generate characteristic multi-field signatures for the ERTS sensors.

To begin with, a definitional elaboration: the multi-'field' designation was implied to cover both the multi-disciplinary/-applicational as well as multi-spatial/-temporal sense. Also, the reference to ERTS sensors was in the context of the distinct spectral band structures for the MSS and the RBV on-board, with an intended comparison of the 4-dimensional versus 3-dimensional responses of the common ground features. Unfortunately, no RBV data was ever gathered on ERTS-1 over Los Angeles.

In so far as all of the machine analysis of ERTS data, in this case on the GEMS and the IMAGE 100, of necessity involves 'generation' of training signatures, either supervised or unsupervised learning-wise; this objective as phrased in the proposal might be construed to be incidental to the third objective below. However, implied in the 'generation' was the 'existence' of signatures for the 'fields', per se: namely, possibly independently available and usable over "large" spatial extents and temporal spans.

Accordingly, in the experimental translation of this objective, the COLAGE investigators attempted to address modestly to the questions pertaining to the so-called Signature Extension Problem: namely, given a set of ERTS data, acquiring a training signature, with ground truth over the realm of the ERTS data coverage, how far can the training signature be validly used over spatial and temporal ranges in spite of certain known factors that vary slightly over these range?

The problem was tackled rather grossly from the user's view-point with available ground data, i.e., without recourse to any delineation of atmospheric and ephemeric factors. Evaluation of preliminary analysis over only single ERTS frames was attempted spatially, with two or four scenes seasonally, on the GEMS and the IMAGE 100. Relative constancy of the central cores of urban areas contrasted with the variability of the vegetative cover within and around them were used as indicators for these considerations. More systematically designed ground truth data would be required to arrive at specific conclusions with respect to extending signatures beyond an ERTS frame, but within a frame signatures generated in a field-of-view approximately 500 pixels by 500 scanlines could be used in adjoining fields-of-view/analysis areas.

- (3) To ascertain the utility of a multi-spectral analyzer under development through its use by representative multi-resource users.

Over the duration of the investigation two generations of multispectral analyzers under development became available, viz the GEMS and the IMAGE 100 whose designs were carried out in a major fashion by Dr. Economy who in turn participated with other analysts/users in implementing this study objective.

The County coinvestigators found a number of features as well as the outputs of these systems of much interest and innovative potential from a user's view. The interactive aspect of the hands-on analysis was particularly significant. While a measure of technology transfer to a user was accomplished during the participation in this project by the County planners, their primary concern with respect to the long range questions about a sophisticated system such as the IMAGE 100 was the capital and maintenance costs to a local agency for extraction of earth observational information useful for their routine operations. Availability of relatively inexpensive commercial information extraction service or regional centers would determine the degree of future use of ERTS-type data by local agencies.

- (4) To evaluate ERTS imagery utility for developing planning and environmental data bases and information systems.

While formulating this objective, there was an implied expectation of interfacing the outputs of machine analysis with computerized data bases and information systems though this was not explicated with respect to any specific planning and/or environmental agency, local or regional. Even though the outputs from

photointerpretation analysis as well as electronic systems could be and have been demonstrated to be in digital format. These were not reformatted for further manipulation into any existing computerized systems. However, the additional effort for such an interface is relatively direct. Here the emphasis was placed on the assessment of utility of the results of analysis themselves, as discussed in Section 7.

- (5) To investigate the feasibility of using ERTS output for research in urban and regional planning methodologies.

As mentioned in the proposal, this objective was a rather long range one, and one of which the degree of accomplishment needs to be assessed more by the planning community at large. Both the County and the OVAAC8 planners initiated a number of lines of investigation of significance in planning methodologies development. The novelty and uniqueness of ERTS data itself, as well as the flexibility and versatility of the information extraction systems, offer many opportunities here. To mention only a couple of items: the global coverage of ERTS has opened up the possibility, for the first time, to compare, for example, urban areas around the world, as briefly attempted in Section 3. A machine analysis continuation of this substudy is underway. The major substudy of housing types in the residential areas around Los Angeles-Orange Counties described in Section 4 is another example of this effort.

In retrospect, the more immediately accomplishable objectives - first three - were carried out beyond the proposal expectations in view of the remarkable quality of the ERTS data and the sophistication of analysis tools while in the case of the longer range - last two - objectives potentials for further accomplishments were well brought out.

## 8.2 CONCLUSIONS

There is utility in ERTS-1 data for urban and regional planning.

2. It would be desirable for future work of this kind to maintain the synopoticity obtainable in the field of view of a standard ERTS image, i. e., 100 by 100 nautical miles.
3. It would be desirable for ERTS imagery in the future to have higher resolution, perhaps with the ERTS-C series of resources satellites and beyond.
4. The nature of a standard ERTS image in terms of both a wide field of view and multispectrality was unique and unconventional to many planners who are used to working with the traditional land use data sources such as large scale black and white aircraft imagery.
5. The periodicity of global coverage by ERTS every 18 days was judged to be sufficient by the COLAGE investigators to allow for meaningful temporal evaluation of the Los Angeles area.
6. The unconventional and supplemental nature of ERTS-1 products and the nature of the planning process makes it very difficult to measure the cost effectiveness of ERTS-1 products for urban and regional planning.
7. The COLAGE team concludes that attempts at operational use of ERTS-1 data for urban and regional planning have been premature.
8. ERTS products may be more useful as a data source for urban and regional planning in the less developed areas of the world having less elaborate existing data bases and fewer alternative or complementary data sources.

## 8.3 RECOMMENDATIONS

These recommendations are directed at NASA in particular and the remote sensing community in general.

1. NASA should encourage the involvement of land use planners, particularly on such panels as the ERTS land use and mapping seminars. Many of these panels tend to be NASA-centered. It is recommended that a greater voice be given to participants from the U. S. Department of Housing and Urban Development, state planning representatives, and planners from the academic world.

2. It should be recognized that urban and regional planning is a much broader field than land use planning and that land use planning involves much more than gathering current land use data.
3. NASA planners should acquire more precise definitions for such concepts as ground truth and change detection as they apply to remote sensing.
4. More emphasis should be placed on the use of ERTS products for orientation, illustration, base mapping and monitoring for urban and regional planning use.
5. In the future, a more direct approach should be made to planners through professional organizations and large federal, state, regional and metropolitan planning agencies than was done during the ERTS-1 program. This would facilitate the dissemination of information about the planning use of products from satellite-born sensors.

#### 8.4 PROSPECTING FOLLOW-UP EFFORT

As can be gleaned from even a cursory reading of the report so far, the project involved substantial commitment of interest, effort and resources above and beyond the call of the proposal/contract - on the part of the individual team members, their organizations and others. Accordingly, each of the investigator and his institutions would be expected to and indeed have been following-up efforts at least partly arising out of this joint activity. What is outlined in this subsection, however, is a generic outline of desired 'future action' suggested explicitly by the findings from the project. This is in the nature of a 'scope update' of what was in fact proposed by this team for a follow-on investigation on ERTS-B which in turn was a resubmittal of an add-on effort formulated rather very early in the course of this project.

The scope update can be formulated in terms of the twin goals of this effort spelled out via the first three and the last two objectives as assessed in Section 8.1: a) ERTS data characteristics and information extraction implications, and b) multi-disciplinary, multi-regional, multi-jurisdictional operational user evaluations.

In implementing the former, a total ERTS system orientation and effort is deemed necessary, requiring a specific NDPF participation and evaluation. The latter could still be carried out best by involving regional planners in hierarchical test sites/organizational relationships, again with an interactive and evaluational role for NASA and other Federal Agencies personnel.

Perhaps a comparison could be made with the Large Area Crop Inventory Experiment (LACIE) jointly undertaken by NASA/JSC, USDA/FAS and LARS-ERIM: a national land use counterpart of this project is minimally envisioned here. Optimally, both a more comprehensive local, regional, state, interstate and federal users involvement as well as a more thorough system characteristics should be provisioned.

Again, following up the agricultural comparison, the Crop Inventory Technology Assessment for Remote Sensing (CITARS) project was designed sufficiently late into the ERTS-1 mission itself. A COLAGE follow-on fulfilling the same function for land use/regional planning that CITARS performed for LACIE is considered to be minimally required, rather urgently.

## APPENDICES

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## APPENDIX A

### ERTS SYSTEM AND MISSION OVERVIEW

The NASA Earth Resources Technology Satellite Program is one of the major unmanned missions activity of NASA during the current decade. Documentation of the ERTS system (recently renamed the LANDSAT system) is found in the ERTS Reference Manual issued by GE's Space Division, the prime contractor to NASA/Goddard Space Flight Center for the LANDSAT spacecraft. A reference document of particular interest to the readers of this report is the ERTS Data Users Handbook, available from NASA/GSFC.

Here only the broadest items will be briefly reviewed. Figure A-1 shows the overall system elements and their functional relationships. Two types of data acquisition was designed for this mission: the imaging subsystems and the data relay subsystem. For COLAGE, only the earth observational subsystems, viz the Multispectral Scanner (MSS) and the Return Beam Vidicon (RBV), were of interest. Their operations are functionally depicted respectively in Figures A-2 and A-3.

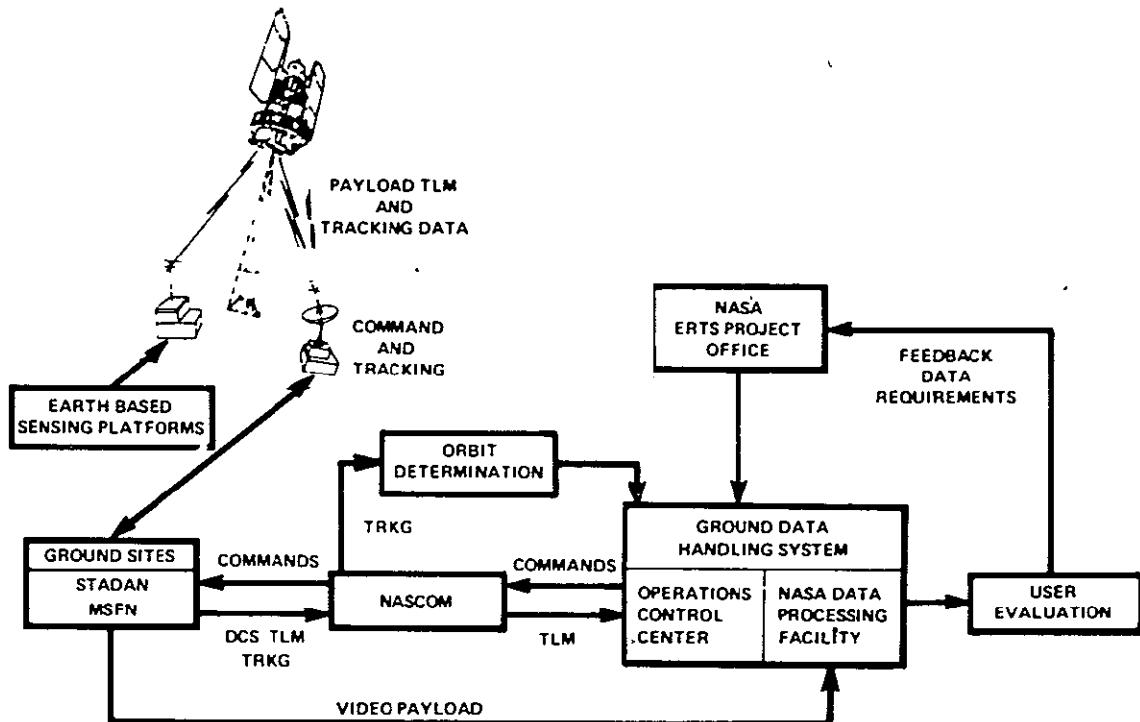


Figure A-1. Earth Resources Technology Satellite System Elements

The MSS scans data continuously, via a mirror sweep, crosstrack over a 100 nautical mile or 185 kilometer wide line, with the downtrack motion of the satellite providing the coverage as shown in the Figure A-2. Six separate detectors view the ground in each of the four bands:

<u>Band</u>	<u>Wavelength (micrometers)</u>
4	0.5 to 0.6
5	0.6 to 0.7
6	0.7 to 0.8
7	0.8 to 1.1

The three RBV cameras, on the other hand, produce images in bands 1, 2, and 3, sequentially viewing the same patch of the ground 185 km by 185 km or 100 nm x 100 nm. The images are scanned on the space-craft and the resulting data is transmitted to the ground receiving stations. Wavelengths in the three bands for the RBV are:

<u>Band</u>	<u>Wavelength (micrometers)</u>
1	0.475 to 0.575
2	0.580 to 0.680
3	0.698 to 0.830

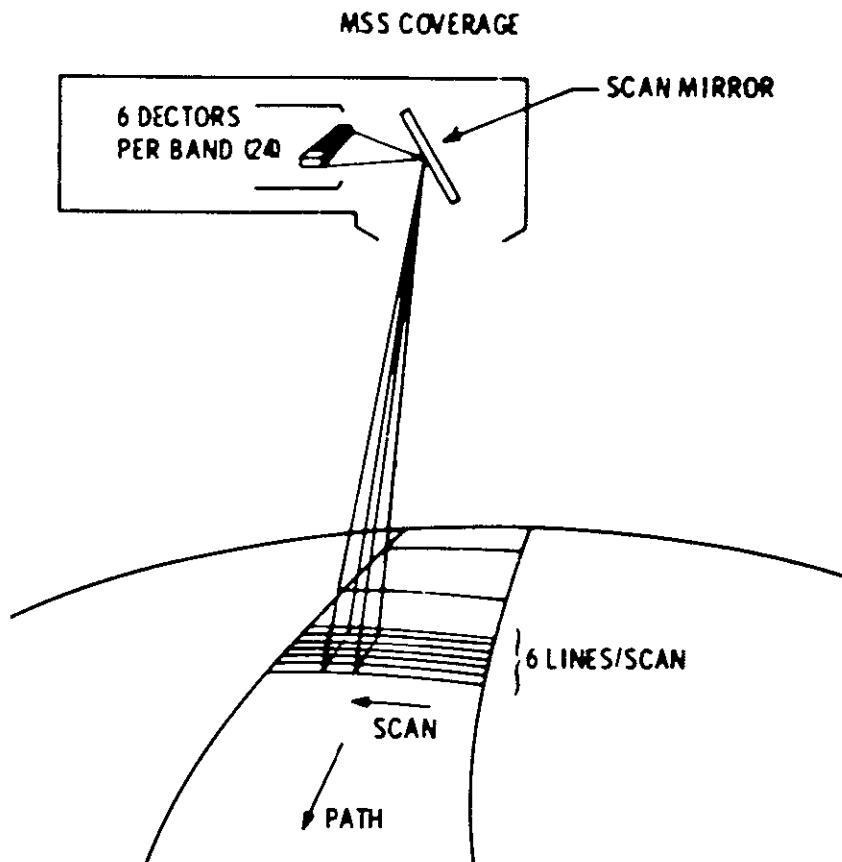


Figure A-2. Multispectral Scanner Data Acquisition

The instantaneous field of view of the MSS is 79 x 79 meters (200 x 200 feet). These picture elements or pixels are so covered that along the scan line there is an over sampling by the sensor, resulting in a 40% overlap of the ground area within successive instantaneous fields of views. The scan rate is adjusted so that downtrack the scan line exactly cover successive strips on the ground 79 meter wide, with no gaps or overlap.

The orbital parameters of ERTS are so adjusted as to locate the spacecraft almost over the same point on the earth approximately every 18 days, or 251 orbits apart. The orbit traces on the ground thus result in a pattern shown in Figure A-4 over the United States.

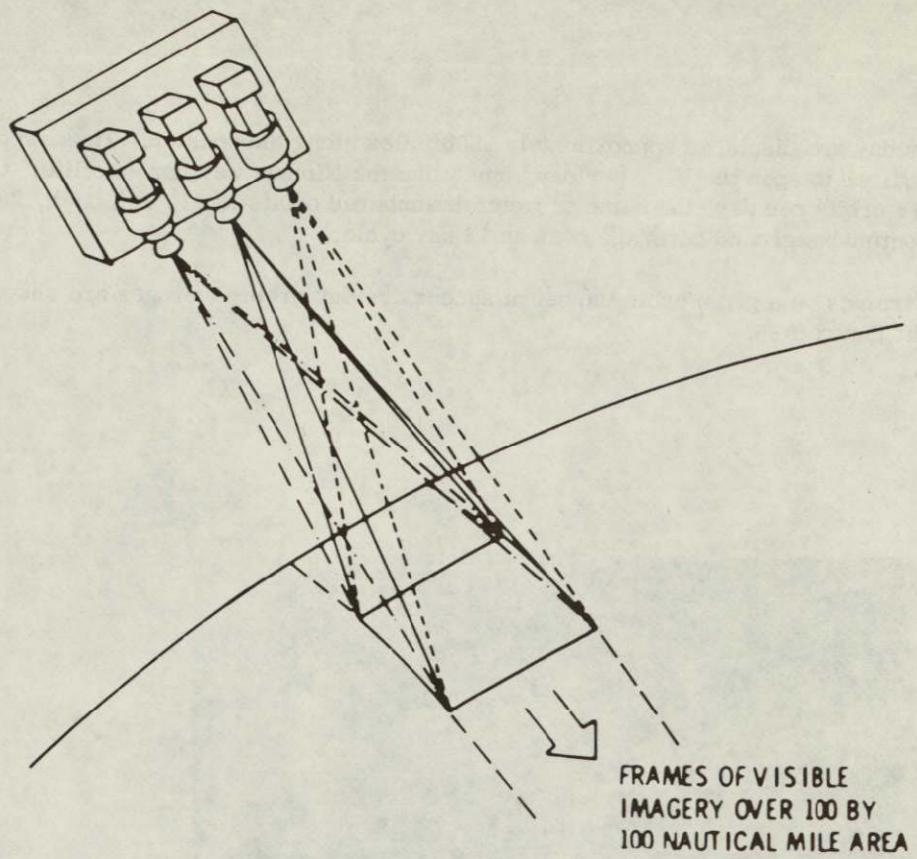


Figure A-3. Return Beam Vidicon Coverage Frames

ERTS-1 COVERAGE OF THE UNITED STATES

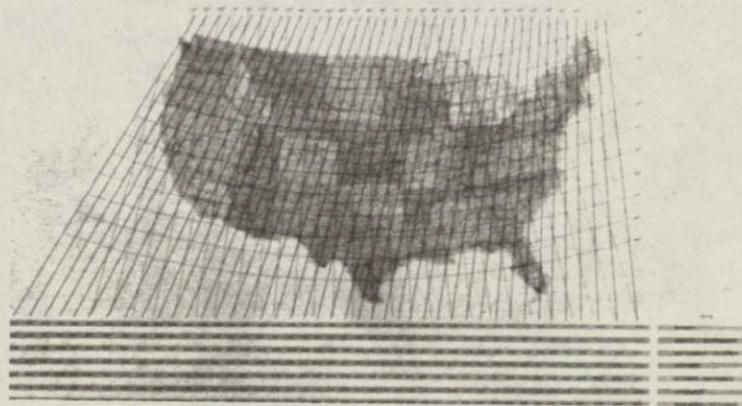


Figure A-4. ERTS-1 Reference Orbit Trace Pattern

Successive orbits on a given day are displaced approximately 1800 miles along the equator. Thus, approximately three orbits are required to span the U.S. per day, much like the Nimbus weather satellite. On successive days, counting 14 orbits per day, the same sequential numbered orbits (e.g., 1st, 15th, 29th) sidelap westward to yield continuous ground coverage over an 18 day cycle.

A typical set of successive frames on a given orbit and set of successive day orbit coverages are shown for the COLAGE Test Site in Figure A-5.



Figure A-5. Typical ERTS-1 Coverage of COLAGE Test Site

APPENDIX B

GENERAL ELECTRIC MULTISPECTRAL INFORMATION  
EXTRACTION SYSTEMS: GEMS AND IMAGE 100 -  
SYSTEM DESCRIPTION AND USE PROCEDURES

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## APPENDIX B

### GENERAL ELECTRIC MULTISPECTRAL INFORMATION EXTRACTION SYSTEMS: GEMS AND IMAGE 100 - SYSTEM DESCRIPTION AND USE PROCEDURES

The development of interactive analysis facilities for multispectral data spans a number of years and locations within the General Electric Company, primarily in the Space Division. Following a prototype laboratory system designed to analyze 2-channel data in real time at the Electronics Laboratory in Syracuse New York, which was being considered for use in the present investigation in the earlier proposal, the 3-channel system at Valley Forge, generally known as GEMS, became operational and was available in time for the early analysis on COLAGE. Figure B-1 is a cutaway illustration of the laboratory version of the system, with the functional elements also shown.

The primary input to the GEMS was the color-composite transparency. The data was scanned by a color TV camera, resolved into three channels filtered-beam-splitting, and digitized. The overall functional flow in the 4-channel IMAGE 100 and the GEMS are generically the same, as shown in Figure B-2, the remainder of the system description and operating principles are best described in terms of the IMAGE 100.

#### B.1 GE APPROACH TO MACHINE-AIDED IMAGE ANALYSIS

In designing multispectral information extraction systems such as GEMS or IMAGE 100, GE engineers strived to incorporate the following characteristics:

1. Real time multispectral image analysis
2. Effective combination of an operator's visual skills and machine signature processing capability
3. Rapid analysis aids
4. Simple straightforward operation
5. Results automatically stored in computer language

Implementation of these design characteristics required a special purpose machine rather than a general purpose computer that could handle only batch processing. The equipment included a real time visual display so the operator could review the data. Such a display allows the operator to interact with the machine and change or modify results to conform with the kind of results desired. These results are re-displayed almost instantaneously allowing an interactive functioning between the operator and the machine.

Data can be analyzed so rapidly that a vast amount of interpreted information is available in a short time.

Simple operation allows the user to become familiar with the machine's operation in a short time. The immediate advantage is a large amounts of meaningful data quickly without having to depend on a specially trained operator.

The machines provide multipurpose outputs that included computer compatible tapes, transparencies and printouts.

The GEMS system includes a color TV camera, multispectral analyzer, analog computer, and combiner display terminal together with controls for each of these units. A color composite image is scanned by the TV camera and separated into three spectral bands: 0.5 to 0.6 micrometers, 0.6 to 0.7 micrometers, and 0.8 to 1.1 micrometers.

The GE IMAGE 100 system is a second generation image analysis machine that differs from the GEMS system primarily because it is a totally digital design. Because of this the IMAGE 100 accepts additional input formats and produces a variety of outputs.

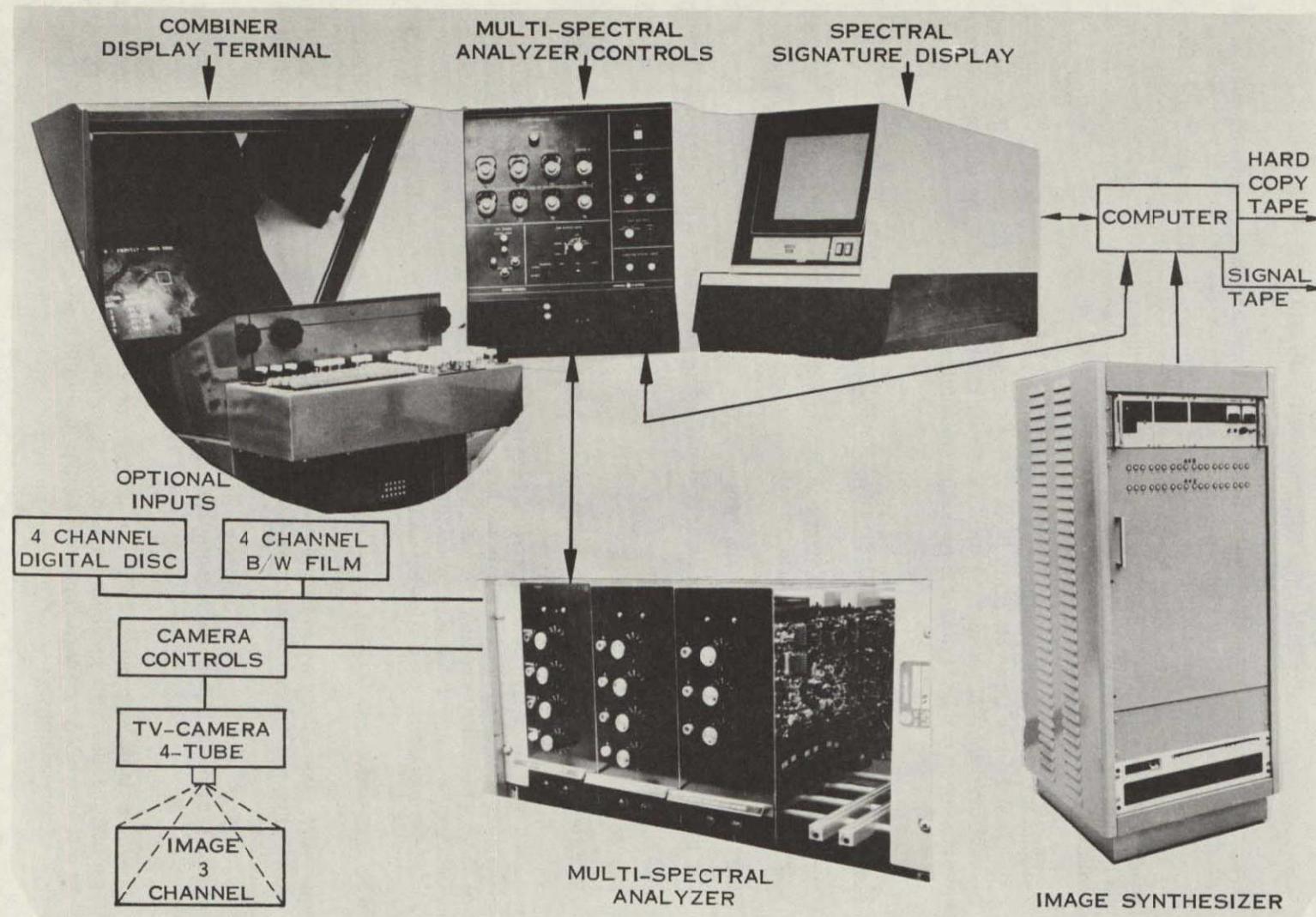


Figure B-1. GEMS System

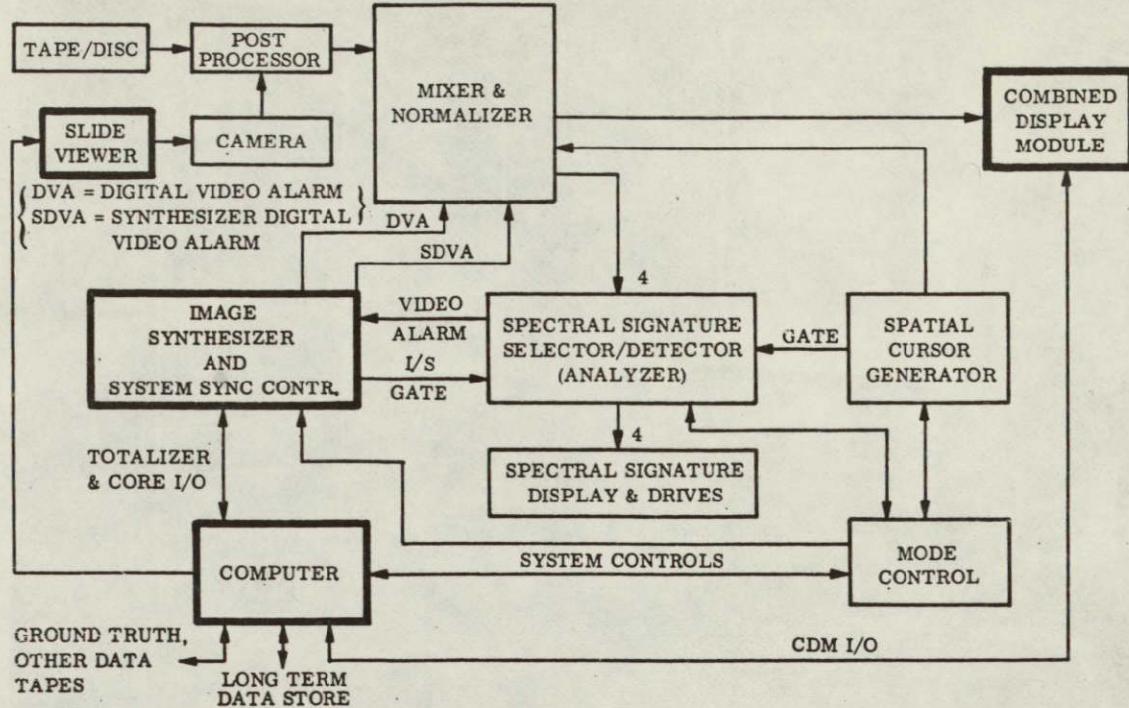


Figure B-2. GEMS Image Analysis System Diagram

## B.2 IMAGE 100 SYSTEM PHILOSOPHY

The prime concept about which all IMAGE 100 design parameters were considered is the efficient operation of the man-machine system. It was assumed from the outset that man will never be completely replaced by a machine; his pattern recognition powers are indispensable. However, the "number crunching" process is too time consuming for the man; therefore, the obvious solution is to build a hybrid system-man and machine. This is General Electric's approach.

In all cases, the man may second guess the computer; an interactive capability to modify computer parameters and decisions is always available; changes are quickly made and evaluated. In fact, in almost all modes of operation, the system responds to the man at least as quickly as he can decide what to do next. The complexity of the system, in addition to the fast response time requirement, necessitated a human factors approach to the man-machine interface. It is shown in Figure B-3. The operator sits directly in front of the primary display device, a color CRT (television monitor). Directly below the CRT is the display control panel, color selector, cursor control, video theme mixing control, etc. Directly to the left of the CRT is the processor control panel; preprocessor controls, theme synthesis controls, and computer interface controls are found here. The panel flow is left to right (towards the display) with a rudimentary block diagram superimposed on the panel (see Figure B-4).

A computer-graphics display terminal is located between the logic unit and the computer; here responses to computer requests, as initiated by the control panel switches, are made. Thus, a combination of panel switches and alphanumeric text is employed to make for a relatively fast and efficient software interface. A DEC PDP 11 series computer, with standard peripherals, is used as the system process controller.

The IMAGE 100 has the capability of storing 4-channel imagery, eight bits per channel, and in addition, eight themes (bi-level classification results overlaid on the video in false color). A standard 500-line format is used, to put the storage requirement at approximately 10 million bits. For this, a rotating disc is used as a refresh and storage device.



Figure B-3. View of the IMAGE 100 System Installed in General Electric's Earth Resources Image Processing and Analysis Center, Beltsville, Maryland

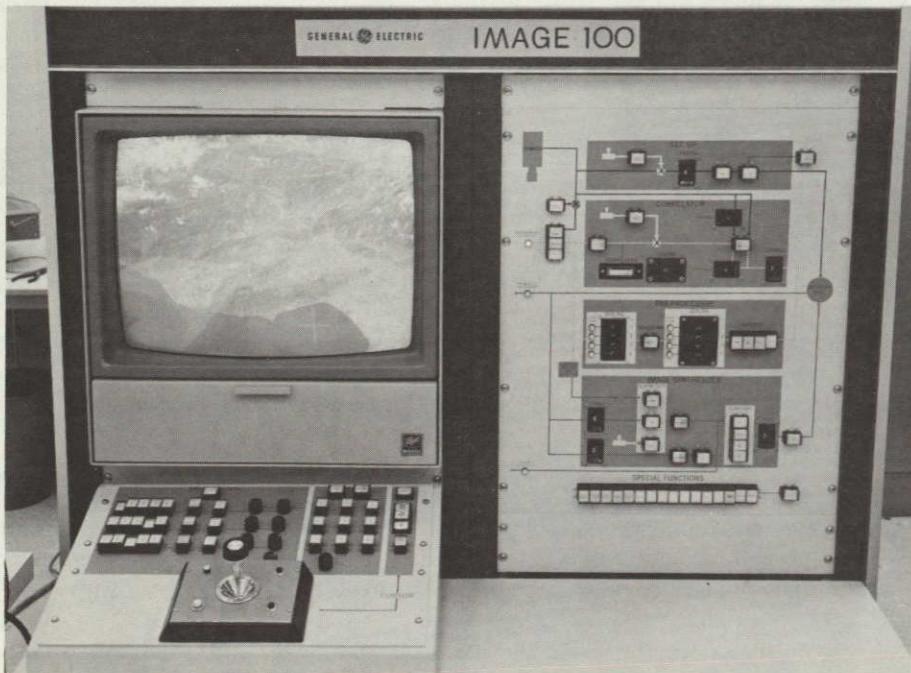


Figure B-4. IMAGE 100 System Controls and Displays/Indicators (Representative View)

The disc may be loaded from either a digitized camera input or via a computer interface. The later allows magnetic tape stored imagery (e.g., ERTS) to be accommodated. The disc data are fed through the pre-processor upstream of the actual signature analyzer and theme synthesizer hardware. The preprocessor consists of special arithmetic processing circuitry to perform various ratioing functions and to perform vector rotations.

The spectral signature analyzer and theme synthesizer hardware is the through extraction portion of the system.

A user specified training area is delineated on an image under analysis through the use of an adjustable cursor. The spectral data within the training area are automatically measured, and their limits used to define a parallelepiped in spectral space.

Up to 4-dimensional parallelepipeds are generated, and results are tabulated, all under computer control. The computer software sets the thresholds defining individual parallelepipeds, the hardware counts the number of pixels (picture elements) falling within each particular parallelepiped (for a given cursor defined training area), and the counts are then sent back to the computer for histogram analysis.

The significance of the histogram approach is that it is completely unbiased; spectral signatures are measured, distributions are plotted - not assumed. Until recently, this approach has not been feasible due to time constraints; for example, a 4-dimensional signature space might contain as many as  $64^4$  parallelepipeds (e.g., ERTS); however, the advent of fast and cost effective digital MSI circuitry and large refresh memory techniques has made the problem tractable. The IMAGE 100 scans 1800 parallelepipeds per minute, or 28,800 per minute when the bi-level testing mode is used. In addition, preprocessing upstream can reduce dimensionality and decrease the time requirement as well as perform a "signature extension" function.

### B.3 SYSTEM THEORY

#### B.3.1 INTRODUCTION

The basic function of the IMAGE 100 (Interactive Multispectral Image Analysis System) is to extract thematic information from multispectral imagery. It is accomplished via statistical measurement of the radiometric properties of the multispectral imagery in conjunction with the operator's visual and statistical interpretation of data presented to him. The IMAGE 100's information extraction capability is only as good as the operator's comprehension of the total information extraction process; a photo-interpreter/statistician user would be an ideal operator (assuming, of course, a complete grasp of the IMAGE 100 concept.)

#### B.3.2 DEFINITIONS

The definitions of some key image processing terms/concepts follows:

1. Training - The process of informing the system which object to analyze, and the system process of identifying the spectral properties of that object is called "training" ("signature extraction" is used interchangeably).
2. Classification - When the spectral properties of the object are found, the IMAGE 100 System scans the total image (pixel-by-pixel) and determines if the spectral properties of each pixel correlate with those of the object of interest. This testing process is called "classification."
3. Pixel - Picture element.
4. Theme - Class type, binary map, bi-level map, alarm, classification result. "Theme" is usually differentiated from "alarm" in the sense that themes are stored while the alarm is generated in real time by the set of spectral limits defining the original parallelepiped.
5. Gray Level - A digital processing system quantizes or digitizes a continuous distribution of data values into discrete levels. When referring to radiometric values of an image the digitized levels are called gray levels. This derives from the way a black and white photograph of a single spectral image represents different radiometric values as shades of gray.

6. Signature - A multispectral signature defines the characteristics of a given object or material as a function of its reflectance of electromagnetic radiation at a number of discrete wavelengths (visible and/or nonvisible). "Cluster" is often used synonymously (see Figure B-5).

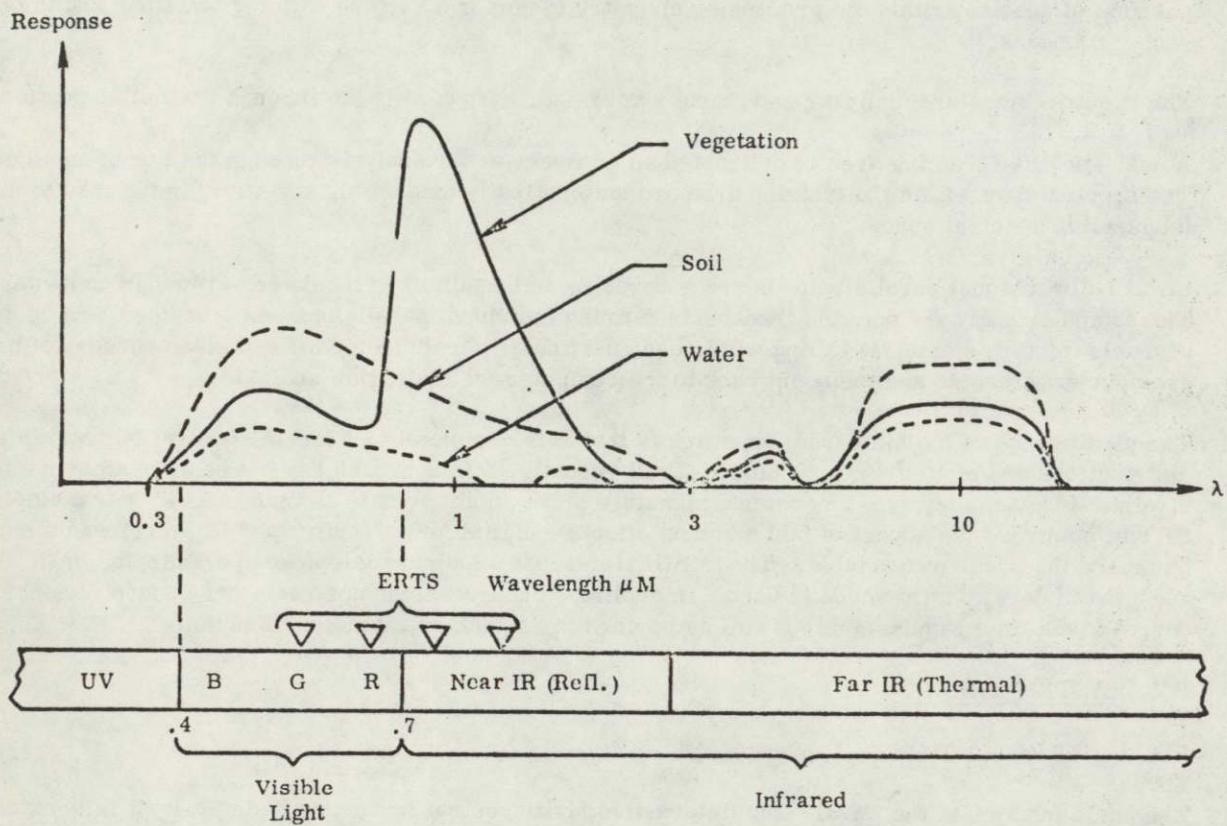


Figure B-5. Typical Material Signatures

7. Training Site - A spatial area, usually consisting of one object or material type, which is used as the data base for determining the object's spectral signature.

8. Histogram - A frequency distribution. In the IMAGE 100, gray levels are plotted against pixel counts (enclosed within the training area only).

9. Parallelepiped - The set of gray levels describing a region in spectral space. In two dimensions, 2 pairs of upper and lower gray level limits describe a rectangle; in three dimensions, 3 pair describe a parallelepiped; in four dimensions, 4 pairs describe a hyperparallelepiped. Often used synonymously are the terms "cell" and "hypervolume."

10. Maximum Likelihood Rule - A statistical decision criteria to assist in the resolution of overlapping signatures; histogram comparisons are the basis of the criteria.

11. Preprocessor - As applied to the IMAGE 100, this refers to data processing of the raw multispectral imagery prior to signature extraction and classification.

12. General Purpose Transformation - This is a preprocessing function which performs rotation of axis in spectral space. The transformation has three modes of operation: 1) all axes are rotated 45 degrees, 2) all axes are rotated to align with machine calculated eigen vectors, and 3) axes are rotated to user specified angles.

13. Ground Truth - Data which have been acquired via field tests, high resolution remote sensors, etc., and used as control information by the user during the information extraction process.

14. Channel - Dimension, feature, wavelength, band, video axis, when used as descriptors. Specifically, channel refers to a one dimensional set of gray levels which usually represent a single spectral image.
15. Cluster Display - The display of histogram data is in 2-dimensional format; i.e., two bands are cross-plotted in terms of log base  $\sqrt{2}$  of the pixel counts contained within the cells. Scattergram is used synonymously.
16. Cell - A cell is described by N pairs of upper and lower density thresholds. For example, when N = 1, a cell is defined between two gray levels; when N = 2, a cell can be described as a rectangle in signature space; when N = 3, a cell is a parallelepiped. A resolution cell is the smallest definable cell based on user-selected density quantization intervals (i.e., the "effective quantization"). A one dimensional resolution cell is identical to one gray level.

### B.3.3 INFORMATION EXTRACTION TECHNIQUES

The thematic extraction process is achieved via the following techniques in approximately the sequence as presented below:

1. The multispectral image to be classified into themes is loaded onto the refresh device.
2. Preprocessing functions and display controls are selected and adjusted for visual enhancement of area(s) of interest. Image enlargement or magnification can also aid this visual discrimination process.
3. A training site is identified by use of the cursor. If a geographically contiguous training site has been selected, the cursor is adjusted in both size and shape to fit within the site boundary. If it is non-contiguous, any number of cursored areas may be combined by using the theme synthesizer function. Note that a single pixel may be identified as the training site by selecting the cross-hair cursor mode and by formatting the image in 2x format or greater.
4. The training site signature is now extracted via the "1-dimensional" training procedure. The histogram is acquired for each dimension individually; upper and lower limits are selected for each based on user specified rejection levels (i.e., percent of area under the histogram curve). This set of limits defines the multi-dimensional parallelepiped which is the first cut approximation to the training site signature.
5. The classification of the entire image is immediately performed following completion of the one-dimensional signature acquisition. The alarm is displayed on the CRT; errors of commission and/or omission are evaluated.
6. Step 5. may be adequate for certain class types. If not, the user may enter, at his option, any combination of several different modes of operation:
  - One-dimensional histogram modifications.
  - Interactive signature acquisition.
  - Multidimensional signature acquisition.

Or, he may choose to pick a different training site and repeat the entire procedure. The new training site can be combined with the original site or used alone. Previous thematic results can also be used as training sites.

- a. One-Dimensional Signature Modification - Upper and lower limits may be modified, one at a time, in this mode. For example, if the histogram of one band of imagery indicated a binodal distribution the user could truncate the limits for that band so as to include only one node. Also, noise (in the data base) could cause the limits to be too inclusive; in this mode the user could manually override the computer's decision and decrease the appropriate limit(s).

b. Interactive Signature Acquisition - In this mode, the misclassified areas in the scene (as determined by the user) are used to refine the single-parallelepiped representation of the signature decision boundaries. The procedural steps involved are illustrated in Figure B-6.

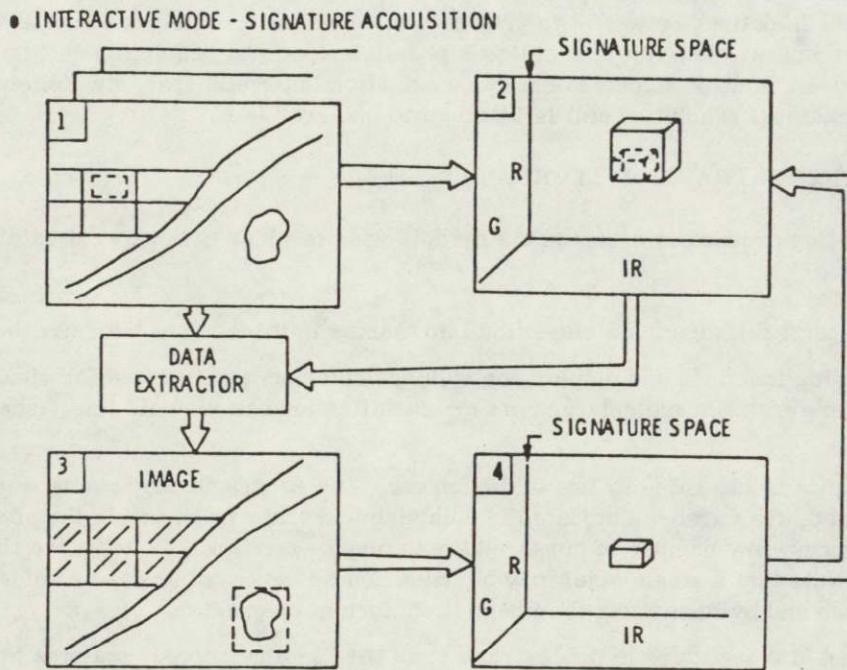


Figure B-6. Interactive Signature Acquisition Technique

In Step 1, the user places the cursor around the object or feature of interest to define the training area. IMAGE 100 then performs a "1-dimensional acquisition." These limits, which define the parallelepiped-shaped signature approximation shown in Step 2 (Figure B-6) are sent to the "signature Analyzer" where all pixels in the scene (input image) are tested to find like objects. Since the signature is a gross approximation, false alarms (misclassifications) can occur as shown in Step 3. The user, based on his knowledge of the scene, can then place the cursor over a falsely alarmed area (as shown in Step 3) and can instruct IMAGE 100 to determine the signature boundaries for the falsely alarmed region. The result is a new parallelepiped, depicted in Step 4, which is then effectively subtracted (or added, if the area was an omission) from the original parallelepiped, leaving the L-shaped decision regions shown in Step 2 which are utilized to reclassify the input image.

This process of signature region optimization can be continued until the user's knowledge of the scene is exhausted or until satisfactory results are achieved.

c. Multidimensional Signature Acquisition - In this semiautomatic mode of operation, the hyper-volume contained within the 1-dimensional parallelepiped (obtained as the initial step of any mode) is sliced into many small parallelepiped subregions, and the number of training area pixels in each small subregion is counted. Figure B-7 illustrates this process. The sub-region boundaries and the individual pixel counts within these boundaries represent a 4-dimensional histogram or cluster of the training area's signature distribution. The histogram is the fundamental measurement that can be made on a signature distribution; it

represents the actual shape of the distribution from which the first and second moments can be derived (i.e., it contains all measurable statistical parameters).

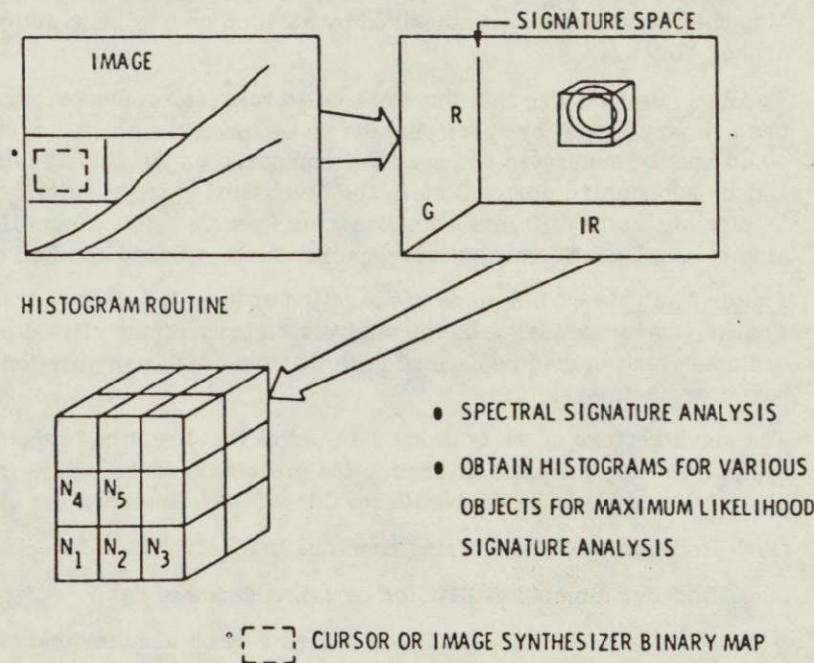


Figure B-7. Statistical Signature Evaluation Technique

7. Once the  $N$ -dimensional histogram has been developed, the user has many options available to him to further exploit the data. They include:

- Histogram displays.
- Histogram thresholding.
- Cluster synthesis.
- Factor Analysis.

a. Histogram Displays:

(1) Cluster Display. This is the projection of a selected pair of spectral axes, expressed as the log base  $\sqrt{2}$ .

(2) Main Cell. This printout lists all cells in sequence, from maximum pixel count to minimum pixel count. This printout also crossplots the spectral separation of all histogram cells; this allows the user to locate multidimensional nodes. Thus decisions may be based on both pixel count and cluster shape by using this printout; it would be referred to whenever operating in the histogram thresholding mode or the cluster synthesis mode.

b. Histogram Thresholding - Based on the "main-cell" cross-reference printout, the user would select an appropriate threshold to reduce the number of empty or near empty cells. An "empty cell" is a parallelepiped with no pixel counts associated with it. The percent reduction in total number of cells in the signature is often large; this is significant since machine classification time is directly proportional to the number of cells in the signature.

c. Cluster Synthesis - This is similar to the theme synthesis function, except that operations take place in the spectral domain instead of the image domain. Cluster synthesis can be accomplished either automatically or manually. The automatic cluster synthesis program will divide the training area spectral distribution into any user specified number of clusters. Manually, clusters are synthesized by addition and/or subtraction of user-specified cells and/or slices.

To illustrate, assume that the main-cell cross-reference printout indicated the presence of two primary nodes; by specifying the nodes using the cluster synthesis function, two themes could thus be generated and spatially compared on the CRT display. By interactively adding and/or subtracting adjacent cells and by observing the resultant thematic displays, overlapping signature differentiation becomes feasible. (Maximum likelihood analysis could also be employed to resolve overlapping clusters based on pixel counts alone.)

d. Factor Analysis - This mode of operation enables the user to transform the spectral space. That is, by performing a factor analysis on the training site data, a transformation or coordinate rotation may be defined such that the cluster in question is optimally "fit" by the new coordinate system.

The eigen vectors of the training data define the direction of the axes of the new coordinate system; the eigen values determine the magnitude of the cluster spread in each axis. The potential benefits to be derived from this analysis include:

- (1) Reduced machine training time due to a better fit of the cluster by the parallelepipeds.
- (2) Reduced dimensionality (for certain classes of data).

A manually selected set of rotation angles may be used instead of factor analysis; this provides a "quick look" capability of transformed imagery.

8. Signature Extension - Signature extension refers to the ability to extend classification over large geographical areas based on relatively small training sites. Special purpose "ratioing" hardware in IMAGE 100 aids this signature extension function at display rates.

The three IMAGE 100 ratioing techniques selectable by the user are:

$$\frac{S_i'}{S_j'} \quad (\text{ratio}) \quad (1)$$

$$\frac{S_i' - S_j'}{S_i' + S_j'} \quad (\text{Difference over sum}) \quad (2)$$

$$\frac{\sum S_i'}{n} \quad (\text{Normalization}) \quad (3)$$

$$i = 1$$

Where  $i$  and  $j = 2$  adjacent channels (i.e.,  $i \neq j$ ,  $j = i + 1$ )

Multiplicative systematic errors are not present in any of the ratioed signals. The second technique, Equation 2, also tends to reduce the additive errors and has a computational advantage of being bounded (i.e., between +1 and -1).

The third technique, Equation 3, is referred to as normalization and is applied when the systematic errors are approximately independent of wavelength; normalization is also numerically bounded.

#### B.3.4 BASIC OPERATING SEQUENCE

The basic operational flow is depicted by Figure B-8. Note that the flow is highly repetitive. After each machine operation, the user must evaluate the results and decide upon the next course of action. Thus, the "women in-the-loop" concept is essential to the system operational flow; the system will extract information whose utility is a direct function of the system operator's ability to operate the machine and evaluate its outputs.

The first stop after powering up is to load and display an image. The loading process itself can be repetitive; an image previously thought to contain useful information may be found to be completely useless after visual inspection on the CRT. Or, the user may wish to pick several areas of interest from an overview (i.e., sampled image) before discarding the overview.

Once the image of interest has been loaded to the user's satisfaction, the training area or areas must be selected. To assist the user in his selection of training areas, he may magnify any portion of the display image by using a preprogrammed window subroutine which takes any cursor defined area and enlarges it by a user specified factor then displays this enlargement in a "window." Often, individual picture elements are of interest, and by "windowing" he may visually inspect them. Once the training area has been selected by the user, he indicates his decision to the machine by means of the cursor. Further, the theme synthesizer may be employed such that a "composite" cursor is generated. In this fashion combinations of previously stored thematic results or virtually any arbitrarily shaped training area may be defined, contiguous or non-contiguous, homogeneous or non-homogeneous.

Once the training area has been selected and so indicated to the machine by means of the theme synthesizer training area controls, 1-dimensional signature acquisition is initiated. At the completion of the 1-dimensional signature acquisition, the user arrives at a major break point. Based on his evaluation of the display, 1-dimensional histogram display, and his knowledge of ground truth, the user may decide to:

1. Store his results and terminate
2. Repeat the process using different parameter values
3. Repeat the process using preprocessing function(s)
4. Modify the results by performing interactive signature acquisition
5. Modify the results using the 1-dimensional signature modification capability
6. Perform multidimensional signature acquisition
7. Perform a combination of the above

Multidimensional signature acquisition measures all available radiometric information by generating the histogram for the training area. Following this operation, the user has many more options available to him:

1. Thresholding, which classifies the entire image based on a user-selected parameter
2. Cluster display/print, which allows him to view projections of the signature
3. Main cell cross-reference plot, another statistical representation of the signature
4. Cluster synthesis, the multidimensional analogue to 1-dimensional histogram modification
5. Preprocessing, including ratioing and transformations
6. Storage of results and termination or selection of new training area or selection of another image
7. Repetition of 1-dimensional acquisition with different parameter values and then repetition of multidimensional signature acquisition
8. A combination of the above

# IMAGE 100 SYSTEM OPERATION

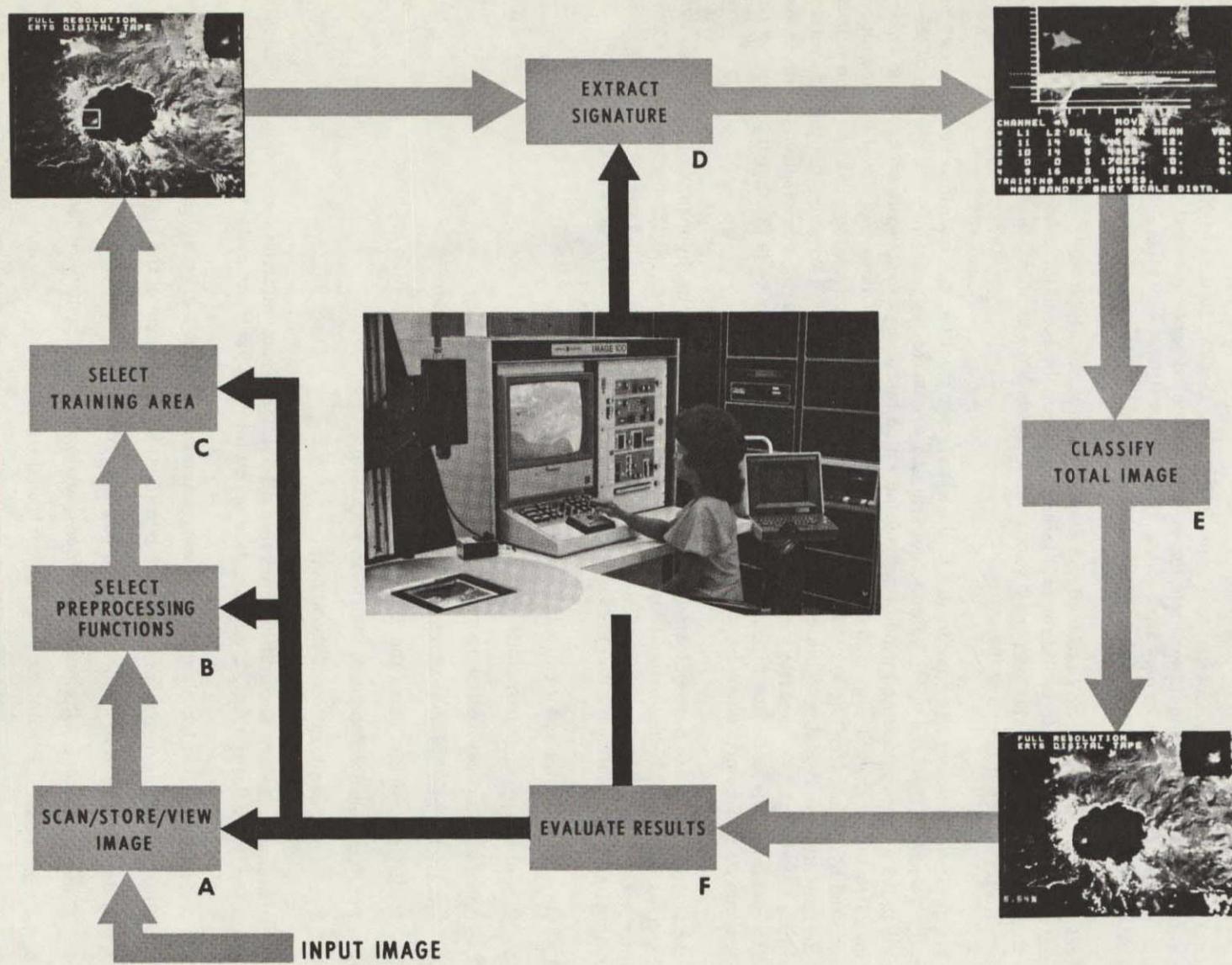


Figure B-8. System Operation Flow Diagram

**APPENDIX C**  
**EXERPTS FROM FLIGHT SUMMARY REPORTS**

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**National Aeronautics and Space Administration**

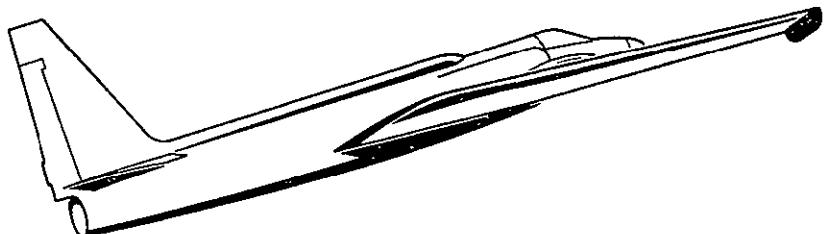
**Earth Resources Aircraft Project**

**Flight Summary Report**

**Flight No.** 72-215

**Date** 14 December 1972

**FSR- 213.**



**Airborne Science Office**

**Ames Research Center, Moffett Field, California**

22 December 1972

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## **FLIGHT SUMMARY**

72-215

This is an ERTS-1 Aircraft Support flight for Proposal No. 124 (Raje) covering the Los Angeles Basin and much of the surrounding area (see Track Map).

All coverage is cloud-free except for valley fog around the Grapevine area. The photography is all of good quality with no camera or processing malfunctions noted.

Due to an error in setting the RC-10 camera clock, the times for this camera are approximately 1-1/2 minutes behind true GMT. The Vinten camera times are actual GMT.

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**FLIGHT LINE DATA****FLIGHT NO.** 72-215

Check Points	Frame Numbers	*Time (GMT - hr, min, sec)		Altitude, MSL (feet)	Cloud Cover/Remarks
		START	END		
VINTEN	A-B	0001-0011	18 41 07	19 49 05	65,000 40-10% Valley fog frs. 1, 2 - rest clear
	C-D	0012-0023	18 52 26	19 00 37	" Clear
	E-F	0024-0037	19 03 28	19 13 32	" "
	G-H	0038-0048	19 16 36	19 24 52	" "
	I-J	0049-0060	19 27 27	19 36 34	" "
	K-L	0061-0073	19 39 07	19 48 35	" "
	M-N	0074-0089	19 51 21	20 02 58	" "
	O-P	0090-0084	20 10 50	20 14 06	" "
RC-10	A-B	7072-7080	18 39 30	18 47 25	65,000 40-10% Valley fog frs. 7072, 73 - rest clear
	C-D	7081-7090	18 50 52	18 58 54	" Clear
	E-F	7091-7102	19 01 52	19 11 56	" "
	G-H	7103-7113	19 15 02	19 23 18	" "
	I-J	7114-7124	19 25 51	19 35 00	" "
	K-L	7125-7135	19 37 31	19 47 00	" "
	M-N	7136-7148	19 49 45	20 01 14	" "
	O-P	7149-7153	20 09 12	20 12 35	" "

\* Setting error in clock - times listed are approx. 1-1/2 minutes behind true GMT (see Vinten times for actual GMT)

EARTH OBSERVATIONS AIRCRAFT PROGRAM  
PROJECT SUPPORT PLAN  
FOR  
ERTS PROJECT I24  
AIRCRAFT TEST SITE  
289 - LOS ANGELES COAST, CALIFORNIA

AIRCRAFT

NCI30B



*National Aeronautics and Space Administration*  
**LYNDON B. JOHNSON SPACE CENTER**

*Houston, Texas*

October 1973

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
LYNDON B. JOHNSON SPACE CENTER  
HOUSTON, TEXAS

EARTH OBSERVATIONS AIRCRAFT PROGRAM  
PROJECT SUPPORT PLAN  
FOR  
ERTS PROJECT I24

APPLICATION OF REMOTE SENSING TO URBAN DEVELOPMENT

J. Lindemann

Prepared By J. Lindemann 10-31-73  
Aircraft Project Manager

C. Harlan

Approved By: Chief, Aircraft Applications Branch

E. Kranz

Approved By: Chief, Flight Control Division

O. Smistad

Concurrence By: Earth Resources Program Office

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1.0 PROJECT DESCRIPTION	PROJECT NUMBER ERTS 124	
APPLICATION DISCIPLINE Urban Development		
1.1 PROJECT OBJECTIVE  <p>The research objectives are to (1) design and develop a compatible system to incorporate regularly gathered remote sensor data from satellites in urban planning and management systems; (2) develop data bases, maps, and standards for identifying and measuring urban changes to be registered by satellites; and (3) initiate an atlas of urban changes to be revised and expanded as data from satellites become available. The technical objectives are to (1) obtain medium-altitude mosaic photography at the desired small-scale of 1:24,000 for the required data base against which urban changes can be measured by means of satellite data, (2) determine the potential of multispectral photography for its application in analyzing and identifying urban change phenomena (3) determine the limits of accuracy attainable in delineating urban land use categories and detecting urban changes from space imagery on ERTS imagery, (4) assess the performance of black-and-white IR and color IR imagery at larger scales in recording urban changes, and (5) determine film and filters most suitable for delineating urban land use.</p>		
1.2 HISTORY AND RELATIONSHIPS TO OTHER INVESTIGATIONS  <p>U2 aircraft have underflown ERTS A for high-altitude comparison.</p>		
1.3 PROJECT REQUIREMENTS  <p>One flight prior to December 15, 1973. As close to ERTS A pass on November 21, 1973, or December 9, 1973 as possible.</p>		
1.4 PERSONNEL		
<u>FUNCTION AND NAME</u>	<u>AFFILIATION AND ADDRESS</u>	<u>TELEPHONE</u>
Principal Investigator Surenda Raje	General Electric Company P.O. Box 8555 Philadelphia, PA 19101	215-962-1177
Project Manager	J. L. Lindemann NASA JSC Code FC2 Houston, TX 77058	713-483-6308

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2.0 OPERATIONAL REQUIREMENTS	PROJECT NUMBER ERTS 124
2.1 Additional requirements and constraints to include preflight/postflight notification and ground truth/air-ground conditions as listed below:	
CLOUD COVER: <20%	
SUN ANGLE: Consistent with good photographic practices for November - December time frame. @ 25°	
ALTITUDE (MAX-MIN): 30 000 ft & 12 000 ft	
PI NOTIFICATION: Yes	
COMMUNICATIONS: No	
ONBOARD OBSERVERS: No	
GROUND TRUTH: Yes	
OTHER:	

## 2.2 PROJECT FLIGHT REQUIREMENTS SUMMARY

PROJECT NUMBER ERTS 124

AIRCRAFT TEST SITE NO. AND NAME	SECTOR	DATA FLT	FLT M-D	FLT PRIORITY	OPS PRIORITY	NO. OF FLT	DATA MILES PER FLT	SENSORS				ALT (ABS) K FEET	SPACECRAFT MISSION	FLIGHT TIMING			POTENTIAL AIRCRAFT															
								METRIC	M/B	IR	MSS			TIME TOL	REQUESTED FLIGHT DATES	SUN ANGLE																
289 - Los Angeles Coast, California	2	1	M	1	M	1	600	2	4	1	1	12 30	ERTS A	18 days	Before 12-15-73	25°	NC130B															
					D	1	600	2	4	1	1																					
		M	D	M	D	M	D	M	D	M	D	12 30	ERTS A	18 days	Before 12-15-73	25°	NC130B															
		M	D	M	D	M	D	M	D	M	D	12 30	ERTS A	18 days	Before 12-15-73	25°	NC130B															
		M	D	M	D	M	D	M	D	M	D	12 30	ERTS A	18 days	Before 12-15-73	25°	NC130B															
		M	D	M	D	M	D	M	D	M	D	12 30	ERTS A	18 days	Before 12-15-73	25°	NC130B															
		M	D	M	D	M	D	M	D	M	D	12 30	ERTS A	18 days	Before 12-15-73	25°	NC130B															
NOTES:																																
500 miles of data at 12 000 ft.																																
100 miles of data at 30 000 ft.																																

2.3 SENSOR SYSTEMS CONFIGURATION REQUIREMENTS										PROJECT NUMBER ERTS 124			
DATA FLT	PHOTOGRAPHIC SYSTEMS										ELECTRONIC SYSTEMS		
	PRIORITY	CAMERA	POSITION	FILM		FILTER	LENS	FWD LAP	SIDELAP	INV (SEC)	PRIORITY	SENSOR	SPECIFICATIONS
1	M	RC8	1	Color	S0397	HAZE	6 in.	60%	20%	(a)	M	MSS	Chan 3 to 9 incl
1	M	RC8	2	Color IR	2443	12	6 in.	60%	20%	(a)	D	MSS	Chan 1, 2, 10 to 24 incl
1	M	HASS	1	Color	S0397	HAZE	40mm	60%	20%	(a)	M	RX IV (b)	8-14 $\mu$ m
1	M	HASS	2	Color IR	2443	12	40mm	60%	20%	(a)	D	RX IV (b)	8-14 $\mu$ m
1	M	HASS	3	B&W IR	2424	89B	40mm	60%	20%	(a)			
1	M	HASS	4	B&W	2402	2A	40mm	60%	20%	(a)			

NOTES:

<sup>a</sup>To be determined by on board photographer.

<sup>b</sup>RX IV mandatory on lines at 30 000 ft and desirable on lines at 12 000 ft.

## 2.4 SENSOR REQUIREMENTS RATIONALE

PROJECT NUMBER ERTS 124

RC8 (M) } Color and color IR film for identification of housing, street conditions, open areas, refuge, etc., are to be surveyed for physical conditions and correlation studies relative to the health status of citizens.

HASS (M) } MSS (M) } RX IV (M) } Provide thermal map, and multispectral information of data observed with the cameras.

60% forward lap is required for stereoptic coverage which greatly facilitates identification and classification of subject matter.

2.5 FLIGHT LINE INSTRUMENTATION SUMMARY								PROJECT NUMBER ERTS 124					
TEST SITE 289			AIRCRAFT NC130B		RC8-1	RC8-2	Hass-1	Hass-2	Hass-3	Hass-4			
LINE	RUN	TIME	ALT (K FT)		LINE								
			MSL	ABS	N. MI.								
1	1		12	12	6.5	M	M	M	M	M	M		
2	1		12	12	25	M	M	M	M	M	M		
3	1		12	12	34	M	M	M	M	M	M		
4	1		12	12	33	M	M	M	M	M	M		
5	1		12	12	36.5	M	M	M	M	M	M		
6	1		12	12	41	M	M	M	M	M	M		
7	1		12	12	44.5	M	M	M	M	M	M		
8	1		12	12	47.5	M	M	M	M	M	M		
9	1		12	12	41	M	M	M	M	M	M		
10	1		12	12	34	M	M	M	M	M	M		
11	1		12	12	32.5	M	M	M	M	M	M		
12	1		12	12	29	M	M	M	M	M	M		
13	1		12	12	14	M	M	M	M	M	M		

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2.5 FLIGHT LINE INSTRUMENTATION SUMMARY										PROJECT NUMBER ERTS 124			
TEST SITE 289													
DATA FLIGHT 1			AIRCRAFT NC130B										
LINE	RUN	TIME	ALT (K FT)	LINE		RC8-1	RC8-2	Hass-1	Hass-2	Hass-3	Hass-4	RX IV	MSS
			MSL	ABS	N.MI.								
14	1		12	12	8	M	M	M	M	M	M		
15	1		12	12	8	M	M	M	M	M	M		
16	1		12	12	6	M	M	M	M	M	M		
17	1		12	12	6	M	M	M	M	M	M		
18	1		12	12	6	M	M	M	M	M	M		
19	1		12	12	6	M	M	M	M	M	M		
20	1		12	12	22	M	M	M	M	M	M	D	M
21	1		12	12	22	M	M	M	M	M	M	D	M
22	1		12	12	22	M	M	M	M	M	M	D	M
20	2		30	30	22	M	M	M	M	M	M		
21	2		30	30	22	M	M	M	M	M	M		
22	2		30	30	22	M	M	M	M	M	M		

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## 2.6 TEST SITE MAP

TEST SITE 289

PROJECT NUMBER ERTS 124



2.7 FLIGHT LINE COORDINATES		TEST SITE 289	PROJECT NUMBER ERTS 124	
<u>LINE</u>	<u>SOUTH END</u>	<u>NORTH END</u>	<u>LINE LENGTH(NM)</u>	
1	33°43.0'N/118°21.0'W	33°49.0'N/118°24.0'W	6.5	
2	33°42.0'N/118°17.0'W	34°04.0'N/118°31.0'W	25	
3	33°44.0'N/118°15.0'W	34°14.0'N/118°34.0'W	34	
4	33°45.0'N/118°12.0'W	34°14.0'N/118°30.7'W	33	
5	33°45.0'N/118°09.0'W	34°17.0'N/118°29.5'W	36.5	
6	33°43.0'N/118°04.0'W	34°19.0'N/118°28.0'W	41	
7	33°38.0'N/117°58.0'W	34°17.0'N/118°23.0'W	44.5	
8	33°35.0'N/117°53.0'W	34°17.0'N/118°19.5'W	47.5	
9	33°39.0'N/117°52.0'W	34°15.0'N/118°15.0'W	41	
10	33°42.0'N/117°51.0'W	34°12.0'N/118°10.0'W	34	
11	33°43.0'N/117°48.5'W	34°12.0'N/118°07.0'W	32.5	
12	33°45.0'N/117°46.0'W	34°10.0'N/118°02.0'W	29	
13	33°58.0'N/117°51.0'W	34°10.0'N/117°59.0'W	14	
14	34°02.0'N/117°50.4'W	34°09.0'N/117°55.0'W	8	
15	34°02.0'N/117°47.0'W	34°09.0'N/117°51.7'W	8	
16	34°02.0'N/117°44.0'W	34°07.0'N/117°47.0'W	6	
17	34°02.0'N/117°40.8'W	34°07.0'N/117°44.0'W	6	
18	34°02.0'N/117°37.7'W	34°07.0'N/117°40.7'W	6	
19	34°02.0'N/117°34.0'W	34°07.0'N/117°37.5'W	6	
		TOTAL	458.5	
(MSS Lines)				
<u>LINE</u>	<u>WEST END</u>	<u>EAST END</u>	<u>PRIORITY</u>	<u>LENGTH(NM)</u>
20	34°03.5'N/118°33.0'W	34°03.5'N/118°07.0'W	1	22
<u>SOUTH END</u>		<u>NORTH END</u>		
21	33°43.0'N/118°15.0'W	34°05.0'N/118°15.0'W	2	22
22	33°46.0'N/118°17.0'W	34°05.0'N/118°30.0'W	3	22
		TOTAL	66	

3.0 DATA PROCESSING AND DISSEMINATION PLAN								PROJECT NUMBER ERTS 124									
3.1 PHOTOGRAPHIC AND OTHER DATA PROCESSING AND DISSEMINATION INSTRUCTIONS																	
			REQUIRED	PORD PROCESSING	SENSI-PLOTS	ADAS CORRELATION	ENHANCEMENT	SPECTRAL CURVES	DPT	DNT	PRINTS B/W	PRINTS COLOR	ENLARGEMENTS (2x)	REMARKS			
														PI	REDAF	EROS	
RC8		1	x	x	x				2					1	1		
			x	x	x				2					1	1		
		1															
		2															
KA62		3															
		4															
		1		x	x	x			2					1	1		
		2		x	x	x			2					1	1		
HASSELBLADS	<input checked="" type="checkbox"/>	3	x	x	x				2					1	1		
		4	x	x	x				2					1	1		
		5															
		6															
AMPS	<input type="checkbox"/>	1															
		2															
ZEISS		1															
		2															
HI-RES																	
BORESIGHT		IR PALLET															
		MFMR															
		SCATT															
		LASER															
		FSS															
		QUICK LOOK															
MISSION FLIGHT LOGS		3												1	1	1	
		AS-FLOWN FLT MAPS	2											1	1		
		CAMERA COREL RPT	1											1			
G&N TABS																	
G&N PLOTS																	
NOTES:																	



#### 4.0 RESOURCES UTILIZATION SUMMARY

PROJECT NUMBER ERTS 124

NOTE: Estimated film footage does not include footage requirements for blank frames, loading, down loading and sensi-strip.

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### Appendix C, Part III

The following table describes the approximate spectral bounds covered by each of the 24 channels in the multispectral scanner used on the aircraft underflights.

<u>Channel</u>	<u>Spectral Band</u>	<u>Channel</u>	<u>Spectral Band</u>
1	0.38 - 0.40 $\mu\text{m}$	13	2.10 - 2.38 $\mu\text{m}$
2	0.41 - 0.45 $\mu\text{m}$	14	3.65 - 4.00 $\mu\text{m}$
3	0.46 - 0.52 $\mu\text{m}$	15	4.49 - 4.75 $\mu\text{m}$
4	0.54 - 0.58 $\mu\text{m}$	16	6.3 - 7.5 $\mu\text{m}$
5	0.59 - 0.64 $\mu\text{m}$	17	8.5 - 8.9 $\mu\text{m}$
6	0.65 - 0.69 $\mu\text{m}$	18	9.0 - 9.5 $\mu\text{m}$
7	0.71 - 0.76 $\mu\text{m}$	19	9.5 - 10.2 $\mu\text{m}$
8	0.77 - 0.81 $\mu\text{m}$	20	10.2 - 11.0 $\mu\text{m}$
9	0.83 - 0.88 $\mu\text{m}$	21	11.2 - 11.9 $\mu\text{m}$
10	0.98 - 1.04 $\mu\text{m}$	22	12.2 - 13.0 $\mu\text{m}$
11	1.20 - 1.3- $\mu\text{m}$	23	1.14 - 1.16 $\mu\text{m}$
12	1.53 - 1.63 $\mu\text{m}$	24	1.05 - 1.09 $\mu\text{m}$

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**APPENDIX D**  
**MID-PROJECT REVIEW CONFERENCE**  
**(AGENDA)**

D

APPENDIX D  
MID-PROJECT REVIEW CONFERENCE

- ERTS VIEWS OF SOUTHERN CALIFORNIA -  
REVIEWS OF MULTIDISCIPLINARY RESULTS  
RELATING TO REGIONAL PLANNING AND RESOURCE MANAGEMENT

Co-Sponsors: General Electric Company and Los Angeles  
County Regional Planning Commission

500 West Temple Street  
Los Angeles, Room 381-B

8:30 a.m. - May 4, 1973

Chairman: David Keller, General Electric Company

8:30 - 8:45	Welcome - Announcements	Ernest E. Debs, Los Angeles County Supervisor, 3rd District; O. K. Christenson, Director of Planning, L. A. County; D. Keller, General Electric;
8:45 - 9:15	Keynote Address	J. Tooker, Director, State of California Office of Planning and Research
9:15 - 10:00	ERTS Symposium Summary March 5-9, 1973	S. Freden, NASA/Goddard
10:00 - 10:15	---- Break ----	
10:15 - 10:25	GE-RPC Project Overview	S. Raje, Principal Investigator, General Electric
10:25 - 11:00	ERTS and the Planner	J. McKnight, Los Angeles County Regional Planning Comm.
11:00 - 11:30	GEMS Analysis of ERTS Imagery	R. Economy, General Electric
11:30 - 11:45	Interpretation of ERTS- GEMS Thematic Mapping	J. McKnight
11:45 - 12:00	ERTS-GEMS Land Use Corroboration	M. Sefain, Los Angeles County Regional Planning Comm.
12:00 - 12:15	Implications for Planning Methodology	G. Willoughby, President, OVAAC8 International, Inc.
12:15 - 1:30	---- Lunch ----	
1:30 - 2:00	Southern California Environmental Assessment	L. Bowden, University of California/Riverside
2:00 - 2:20	Urban Atlas Project; Agricultural Interpretation	C. Johnson, University of California/Riverside
2:20 - 2:50	ERTS Inventory of Natural and Cultural Resources in the South Central Coastal Zone of California	R. R. Thaman, University of California/ Santa Barbara

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Program

- ERTS Views of Southern California -  
Reviews of Multidisciplinary Results  
Relating to Regional Planning and Resource Management

Page 2

2:50 - 3:00	----- Discussion -----	
3:00 - 3:15	----- Break -----	
3:15 - 3:45	Significant Geological Results from ERTS I Applicable to Regional Planning	I. Bechtold, Argus Exploration Company
3:45 - 4:00	California Coastal Processes	D. Steller, Rockwell International
4:00 - 4:15	Aircraft Imagery Applications	R. Mullens, Community Analysis Bureau City of Los Angeles
4:15 - 4:45	Summary and Discussion	D. Keller
4:45	----- Adjournment -----	